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The February 2013 assessment of Northern Shrimp (*Pandalus borealis*) off Labrador and Northeastern Newfoundland

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The February 2013 Northern Shrimp (*Pandalus borealis*) assessment was performed for NAFO Div. 2G, Hopedale + Cartwright Channels as well as Hawke Channel + Div. 3K, which correspond to shrimp fishing areas (SFA) 4, 5 and 6, respectively. Status of the resource in each area was inferred, in part, by examining trends in commercial catch, effort, catch per unit effort (CPUE), fishing pattern and size/sex/age composition of the catches. Fisheries independent data were obtained from annual autumn multispecies research bottom trawl surveys into SFA's 5 and 6 (1996-2012), as well as, summer Northern Shrimp Research Foundation (NSRF) - Fisheries and Oceans Canada (DFO) shrimp based bottom trawl research surveys into SFA 4 (2005–12). These surveys provide information on distribution, abundance, biomass, size/ sex composition and age structure of shrimp.

Catches increased from 22,000 t in 1994 to over 114,000 t by 2003-04 due mainly to increases in Total Allowable Catch (TAC). The overall 2004-05 TAC was set at 111,552 t and maintained until 2008-09 when it was increased to 120,344 t. This TAC was maintained through to 2009-10; however, due to operational and commercial constraints, it was not taken. Under the Integrated Fisheries Management Plan (IFMP) Precautionary Approach (PA) framework the SFA 6 TAC decreased by 33 % to 52,387 t by 2011-12 due to resource status declines within SFA 6, resulting in an overall TAC of 87,007 t for that year. Resource status in SFA 6 improved in 2011, therefore, the 2012-13 SFA 6 TAC was increased to 60,245 t; resource indices remained high in SFA 4 therefore the TAC in SFA 4 was increased to 13,018 t resulting in an overall TAC of 96,563 t for the 2012-13 management year. It was anticipated that this TAC will be taken by March 31, 2013.

The SFA 6 large vessel catch per unit effort (CPUE) increased between 1989 and 1997 and oscillated at a high level until 2006-07, thereafter it declined until 2009/10 but has since been increasing. The small vessel CPUE showed a similar pattern. The SFA 5 large vessel CPUE increased from 1992 to 2001 and has oscillated around this higher level since then. Several factors including resource management decisions, market conditions, searching, and distribution of striped shrimp (*Pandalus montagui*) relative to Northern Shrimp, influenced SFA 4 large vessel CPUE bringing into question its use as a fishery performance indicator.

The resource decreased from a peak in 2006 to near 1996 levels in the south (SFA 6); remained near average on the mid Labrador Shelf (SFA 5) and increased in the north (SFA 4).

The SFA 6 fishable biomass index increased from 310,000 t in 1997 to a peak of nearly 670,000 t in 2006 then declined steeply to 295,000 t in 2010, increased to 409,000 t in 2011 before returning to 316,000 t by 2012. The trend in female spawning stock biomass (SSB) index reflected the trend in the fishable biomass index decreasing to 187,000 t in 2012, which is comparable to the beginning of the time series. Annual total mortality among age 4+ shrimp from RV surveys increased from approximately 34 % to 58 % since 2001. In the long term, the exploitation rate index has varied around 15 %. The exploitation rate decreased from 2004-05 to 2009-10 and increased in the following two years.

Research survey SSB was assessed to be in the Cautious Zone, within the IFMP PA Framework, for the third time in the four most recent years. The 2012-13 exploitation rate is expected to be about 15 %. If the 60 245 t TAC is maintained through 2013-14 and taken the exploitation rate will increase to 19 %; the third highest level in the time series.

The SFA 5 fishable biomass index increased from around 90,000 t in 1996-99 to 184,000 t in 2001 and has since been approximately 150,000 t with the 2012 estimate at 147,000 t. Female spawning stock biomass (SSB) index increased from 40,000 t in the 1996-99 period to 96,000 t in 2001 but has since decreased with the 2012 estimate at 63,000 t. The SFA 5 exploitation

rate has varied without trend around 15 % over most of the time series. Annual female total mortality oscillated between about 35-75 % over the period 1998-2011 averaging about 60 %. Research survey SSB was assessed to be in the Healthy Zone within the IFMP PA Framework. The 2012-13 exploitation rate is expected to be about 16 %. If the 23,300 t TAC is maintained through 2013-14 and taken then the SFA 5 exploitation rate will remain at 16 %.

The SFA 4 fishable biomass index increased from 62,000 t in 2005 to 180,000 t by 2009, decreased to 127,000 t in the next year before increasing to 191,000 t in 2012. Similarly, the female spawning stock biomass (SSB) index increased from 35,000 t in 2005 to 140,000 t by 2009, decreased to 71,000 t in 2010 then increased to 110,000 t in 2012. Annual female total mortality oscillated between about 40-50 % over the period 1999-2008. Due to high numbers of ovigerous females, no estimates available since then. Exploitation rate, within SFA 4, has been between 6 % and 9 % since 2007-08 and the current estimate is 7 %. Research survey SSB was assessed to be in the Healthy Zone, within the IFMP PA Framework, and it is anticipated that the 2012-13 exploitation rate will be less than 10 %.

Évaluation de février 2013 concernant la crevette nordique (*Pandalus borealis*) au large du Labrador et au nord-est de Terre-Neuve

RÉSUMÉ

L'évaluation de février 2013 concernant la crevette nordique (*Pandalus borealis*) a été effectuée pour la division 2G de l'Organisation des pêches de l'Atlantique Nord-Ouest (OPANO), les chenaux Hopedale et Cartwright ainsi que le chenal Hawke et la division 3K, qui correspondent respectivement aux zones de pêche de la crevette (ZPC) 4, 5 et 6. L'état de la ressource dans chaque zone a été déduit en partie de l'examen des tendances relatives aux prises commerciales, à l'effort, aux captures par unité d'effort, au régime de pêche et à la composition des prises en fonction de la taille, du sexe et de l'âge. Les données indépendantes de la pêche ont été obtenues à partir de relevés plurispécifiques automnaux de recherche au chalut de fond effectués chaque année dans les ZPC 5 et 6 (de 1996 à 2012), et aussi de relevés de recherche au chalut de fond sur les crevettes dans la ZPC 4 effectués en été par la Northern Shrimp Research Foundation et Pêches et Océans Canada (de 2005 à 2012). Ces relevés fournissent de l'information sur la répartition, l'abondance, la biomasse, la composition en fonction de la taille et du sexe et la structure d'âge des crevettes.

Les prises sont passées de 22 000 t en 1994 à plus de 114 000 t en 2003-2004, principalement en raison des hausses des totaux autorisés des captures. Le total autorisé des captures (TAC) global pour 2004-2005 a été fixé à 111 552 t et il a été maintenu jusqu'en 2008-2009, alors qu'il a été augmenté pour atteindre 120 344 t. Ce TAC a été maintenu jusqu'en 2009-2010; toutefois, en raison de contraintes opérationnelles et commerciales, il n'a pas été pris. En vertu du cadre de l'Approche de précaution (AP) du Plan de gestion intégrée des pêches (PGIP), le TAC de la ZPC 6 a diminué de 33 % pour atteindre 52 387 t en 2011-2012 à cause du déclin de l'état de la ressource dans la ZPC 6, ce qui a donné lieu à un TAC global de 87 007 t pour cette année-là. L'état de la ressource dans la ZPC 6 s'est amélioré en 2011, par conséquent le TAC de cette zone pour 2012-2013 a été augmenté pour se chiffrer à 60 245 t; les indices relatifs à la ressource sont restés élevés dans la ZPC 4, alors le TAC de cette zone a été porté à 13 018 t, ce qui a donné lieu à un TAC global de 96 563 t pour l'année de gestion 2012-2013. On s'attend à ce que ce TAC soit pris avant le 31 mars 2013.

Les captures par unité d'effort (CPUE) des gros navires dans la ZPC 6 ont augmenté entre 1989 et 1997 et ont oscillé à un niveau élevé jusqu'en 2006-2007; elles ont par la suite diminué jusqu'en 2009-2010, mais elles augmentent de nouveau depuis cette période. Les CPUE des petits navires ont suivi une tendance semblable. Les CPUE des gros navires dans la ZPC 5 ont augmenté de 1992 à 2001 et oscillent à ce niveau plus élevé depuis lors. Plusieurs facteurs, y compris les décisions liées à la gestion des ressources, les conditions du marché, la recherche, ainsi que la répartition de la crevette ésope (*Pandalus montagui*) par rapport à la crevette nordique, ont influé sur les CPUE des gros navires dans la ZPC 4, ce qui remet en question l'utilisation de ces captures à titre d'indicateur de rendement de la pêche.

La ressource a diminué après avoir atteint un sommet en 2006 pour revenir quasiment aux niveaux de 1996 dans le sud (ZPC 6); elle est restée près de la moyenne au milieu du plateau continental du Labrador (ZPC 5) et a augmenté dans le nord (ZPC 4).

L'indice de la biomasse exploitable de la ZPC 6 est passé de 310 000 t en 1997 à un sommet de près de 670 000 t en 2006, puis il a baissé fortement pour se chiffrer à 295 000 t en 2010; il est remonté pour atteindre 409 000 t en 2011 avant de retourner à 316 000 t en 2012. La tendance liée à l'indice de la biomasse du stock reproducteur (BSR) femelle reflétait la tendance liée à l'indice de la biomasse exploitable qui a diminué pour se chiffrer à 187 000 t

en 2012, ce qui est comparable au début des séries chronologiques. La mortalité totale annuelle des crevettes d'âge 4+ selon les relevés par navire de recherche a augmenté : elle est passée d'environ 34 % à 58 % depuis 2001. À long terme, l'indice du taux d'exploitation a varié d'environ 15 %. Le taux d'exploitation a diminué de 2004-2005 à 2009-2010, et il a augmenté au cours des deux années suivantes.

On a évalué que la BSR indiquée dans le relevé de recherche se situait dans la zone critique, selon le cadre d'AP du PGIP, pour la troisième fois au cours des quatre dernières années. Le taux d'exploitation pour 2012-2013 devrait se chiffrer à environ 15 %. Si le TAC de 60 245 t est maintenu pendant 2013-2014 et qu'il est pris, le taux d'exploitation augmentera pour atteindre 19 %; ce pourcentage arrive au troisième rang parmi les niveaux les plus élevés dans les séries chronologiques.

L'indice de la biomasse exploitable de la ZPC 5 est passé d'environ 90 000 t pour la période allant de 1996 à 1999 à 184 000 t en 2001 et s'est maintenu à environ 150 000 t depuis, et l'estimation pour 2012 est de 147 000 t. L'indice de la BSR femelle est passé de 40 000 t pour la période allant de 1996 à 1999 à 96 000 t en 2001, mais il a ensuite diminué; l'estimation pour 2012 est de 63 000 t. Le taux d'exploitation dans la ZPC 5 a varié, sans afficher de tendance, pendant la majeure partie des séries chronologiques, s'établissant à environ 15 %. La mortalité totale annuelle des femelles a oscillé entre 35 % et 75 % pendant la période allant de 1998 à 2011, et elle était de 60 % en moyenne. On a évalué que la BSR indiquée dans le relevé de recherche se situait dans la zone saine du cadre de l'AP du PGIP. Le taux d'exploitation pour 2012-2013 devrait se chiffrer à environ 16 %. Si le TAC de 23 300 t est maintenu au cours de 2013-2014 et qu'il est pris, le taux d'exploitation dans la ZPC 5 restera à 16 %.

L'indice de la biomasse exploitable dans la ZPC 4 est passé de 62 000 t en 2005 à 180 000 t en 2009, puis il a diminué pour atteindre 127 000 t dans l'année suivante avant de remonter jusqu'à 191 000 t en 2012. De même, l'indice de la BSR femelle est passé de 35 000 t en 2005 à 140 000 t en 2009, a diminué pour atteindre 71 000 t en 2010 puis a augmenté de nouveau pour se chiffrer à 110 000 t en 2012. La mortalité totale annuelle des femelles a oscillé entre 40 % et 50 % pour la période allant de 1999 à 2008. En raison du grand nombre de femelles ovigères, aucune estimation n'est disponible depuis ce temps. Le taux d'exploitation, dans la ZPC 4, varie entre 6 % et 9 % depuis 2007-2008, et l'estimation actuelle est de 7 %. On a évalué que la BSR indiquée dans le relevé de recherche se situait dans la zone saine du cadre d'AP du PGIP, et l'on s'attend à ce que le taux d'exploitation pour 2012-2013 soit inférieur à 10 %.

INTRODUCTION

The fishery for Northern Shrimp off the coast of Labrador began in the mid-1970s, primarily in the Hopedale and Cartwright (SFA 5) channels (Fig. 1). Annual catches (Fig. 2) increased steadily from less than 2700 t in 1977 to about 4100 t in 1981 but subsequently declined to 1000 t in 1983 and 1984 due to poor markets and high operating costs. Economic conditions improved thereafter, and catches from SFAs 5 and 6 increased to about 7800 t in 1987. In 1988, fishing effort became more widespread as vessels ventured into Div. 2G (SFA 4) where both catch rate and size of shrimp proved to be very attractive to the industry. Additional commercial concentrations of shrimp were located within SFA 6 in a small area east of St. Anthony Basin and in the Funk Island Deep. Catches in both 1988 and 1989 approached 17,000 t and remained in the 14,000-20,000 t range from 1990 to 1993. Exploratory fisheries along the slope of the shelf in SFAs 4, 5 and 6 in 1992 and 1993 revealed commercial concentrations of shrimp in those areas, as well.

Catches from 1994 to 1996 averaged 23,000 t increasing to 85,000 t by 2000, following increases in TAC within SFA 6 where the resource was considered to be healthy and exploitation low. The increases after 1996 were primarily reserved for the development of a small vessel (<100 ft.) fleet which has since grown to include more than 300 vessels.

The overall TAC increased by 26,270 t in 2003. During that year industry was granted a change in management year from calendar (January 1-December 31) to fiscal (April 1-March 31). To facilitate this change, an additional 20,229 t interim quota was allocated to the large vessel fleet and the 2003-04 management period became 15 months in length. The 2004-05 management year was 12 months in duration and total allocations equaled 111,552 t. This TAC was maintained until 2008-09 when it was increased to 120,344 t. This TAC was maintained through to 2009-10; however, due to operational and commercial constraints, it was not taken. Under the Integrated Fisheries Management Plan (IFMP) Precautionary Approach (PA) framework, the SFA 6 TAC was decreased by 28 % to 61,632 t resulting in an overall TAC of 96,252 t for the 2010-11 management year. Resource status declined further in 2010-11 therefore the SFA 6 TAC was reduced by 15 % to 52,387 t resulting in an overall TAC of 87,007 t for the 2011-12 management year. Resource status in SFA 6 improved in 2011, therefore, the 2012-13 SFA 6 TAC was increased to 60,245 t; resource indices remained high in SFA 4 therefore the TAC in SFA 4 was increased to 13,018 t resulting in an overall TAC of 96,563 t for the 2012-13 management year. It was anticipated that this TAC will be taken by March 31, 2013.

During 2007 a seasonal bridging program was established that allows each license holder to fish up to 250 t of unused quota from the previous year or take it from the next year's quota.

All Northern Shrimp fisheries in eastern Canada are subject to the Atlantic Fisheries Regulations regarding territorial waters, by-catches, discarding, vessel logs, etc. These include a minimum mesh size of 40 mm and mandatory use of sorting grates to minimize by-catch of non-target species. Grate size is dependent upon area fished and vessel class. Observers are required on all trips by the large vessel fleet and a target of 10 % coverage has been established for the small vessel fleet though this target is rarely achieved.

This report provides the background research for the February 18-26, 2023 assessment of Northern Shrimp in SFAs 4-6. The assessment is based upon the use of fishery data from observer and logbook datasets when estimating catch rate indices. Bottom trawl surveys provided indices of recruitment, female spawning stock biomass (SSB), fishable biomass and exploitation rate.

METHODS AND MATERIALS

Data were collected from the following sources:

- Canadian observer databases;
- Canadian logbook databases; and
- Canadian autumn multi-species research surveys.

CANADIAN OBSERVER DATABASE

Approximately 13 large (>500 t) fishing vessels and more than 300 smaller (<=500 t; <65') vessels fish shrimp within Davis Strait, along the coast of Labrador and off the east coast of Newfoundland. There is 100 % mandatory observer coverage of the large vessels, while the small vessels have a target of 10 % observer coverage. Observers working on large vessels collect detailed maturity stage length frequency information from random sets. Those working on small vessels collect ovigerous/ non-ovigerous length frequencies from random sets and one detailed maturity stage length frequency per trip. Observers on both types of vessels record: shrimp catches, effort, amount of discarding, weights and length frequencies of by-caught species.

The Observer database was used to determine CPUE for the large vessel shrimp fishing fleet. Observed data were used because that dataset includes the number of trawls and usage of windows (escape openings) whereas the logbook dataset does not. Raw catch-per-unit effort data was standardized by multiple regression, weighted by effort, in an attempt to account for variation due to year, month, number of trawls, vessel (cfv) etc. The multiplicative model has the following logarithmic form:

$$\ln(CPUE_{ijkml}) = \ln(u) + \ln(S_j) + \ln(V_k) + \ln(T_m) + \ln(Y_l) + e_{ijkml}$$

Where: $CPUE_{ijkml}$ is the CPUE for grt k, fishing x number of trawls, in month j during year l (k=1,.....,a; j=1,.....,s; l=1,.....,y);

$ln(u)$ is the overall mean ln(CPUE);

S_j is the effect of the j^{th} *month;*

V_k is the effect of the k^{th} cfv;

T_m is the effect of m number of trawls;

Y_l is the effect of the l^{th} *year;*

e_{ijkml} is the error term assumed to be normally distributed $N(0,\sigma^2/n)$ where n is the number of observations in a cell and σ^2 is the variance.

Standardized CPUE indices are the antilog of the year coefficient. Final models included all significant class variables with the YEAR effect used to track the trend in stock size over time. The difference (or similarity) between the first year parameter estimate and those of subsequent years was inferred from the output statistics.

In order to track only experienced fishers, the standard dataset included only data from vessels with more than two years of shrimp fishing experience. The first year of the fishery for each vessel was removed from the dataset to account for learning. By limiting the dataset to vessels with a history in the fishery we hope to increase our confidence when interpreting results.

CANADIAN LOGBOOK DATABASE

The small vessel CPUE dataset was created using logbook data because all shrimp fishing vessels must complete logbooks, whereas, observer coverage in the small vessel shrimp fishery may be as low as 3 %.

The landings by small and large vessels allowed a comparison with the total observed catches for each fleet. This comparison provided an indication of percent of total catch captured in each CPUE model.

In addition to the normal CPUE models produced for this stock, attempts were made to create more direct indices of resource biomass. This is possible because positional data is provided within both the observer and logbook datasets allowing one to assign catch and effort data to strata that were fished through the years. Once the assignment is complete and catch data have been standardized it is possible to use areal expansion calculations (Cochran 1997) to determine biomass indices. The biomass indices were calculated using SAS code developed by D. Stansbury (pers. comm.). The plots of geographic distribution of catch and catch rates by commercial vessels were created using ACON (Black 1991).

The catch data were standardized by way of:

Small vessel formulae

- Catch-per-unit-effort = catch / effort
- Effort is in terms of hours towed.
- Trawlable unit = average speed in Nmi/hr X (average wingspread in ft /6080.2 ft/Nmi) * 1 hr
- Average speed = 2.2 Nmi / hr. as determined from observer data
- Average wingspread 56 ft (H. Delouche, pers. comm.).

Large vessel standardization formulae

- Single trawl data
- Catch per unit of effort = catch X ((average speed/speed) X (average footrope length/footrope length))/effort
- Average speed = 2.6 Nmi/hr as determined from observer data
- Average footrope length = 226' as determined from observer data

Double trawl data

- Catch-per-unit-effort = (catch X ((2.5/speed)X(456/footrope length))/effort)/conversion factor to single trawl units
- Conversion factor to single trawl units = 1.3 as determined from the catch rate model provided in this report.
- Average wingspread = 103.5'
- Trawlable unit = 2.5 Nmi/hr X (103.5 ft/6080.2 ft/Nmi)*1 hr
- Average speed was determined from the observer dataset while the average wingspread was provided by H. Delouche (pers. comm.).

- The catch data and trawlable units for the respective fleets were used to estimate biomass and average catch within each strata using areal expansion methods described within Cochran (1997) and SAS code produced by D. Stansbury (pers. comm.).

RESEARCH SURVEY DATA

Shrimp abundance, biomass, maturity and carapace length data have been collected since autumn 1995, as part of the Canadian multispecies surveys conducted using the CCG Wilfred Templeman, CCG Alfred Needler and CCG Teleost. Fishing sets of 15 minute duration and a towing speed of 3 knots were randomly allocated within strata, to depths of 1500 m. Set allocations vary by NAFO division. The minimum allocation of sets per unit area ranged from 1 set per 230 sq. Nmi in 3K to a minimum of 1 set per 350 sq. Nmi in 3N. Please note that spatial expansion programs used by many assessment biologists require that a minimum of 2 sets be placed in each stratum, therefore all strata have a minimum of 2 sets and the number of sets allocated by area may be much higher than 1 set per 230 sq. Nmi identified above. All vessels used a Campelen 1800 shrimp trawl with a 40 mm codend mesh size and a 12.7 mm liner. SCANMAR sensors estimated that the mean wingspread was 16.8 m.

The Teleost normally begins the survey by fishing in NAFO Div. 3O at depths >750 m and continues eastward until the deepwater in NAFO Div. 3N is complete. The Teleost then proceeds to the northern limit of NAFO Div. 2J and fishes southward in all depths. The Wilfred Templeman and Alfred Needler are sister ships and begin the fall survey in waters shallower than 750 m in NAFO Div. 3ONL and finally meet with the Teleost in 3K at the end of the survey, normally during December. Details of the survey design and fishing protocols are outlined in (Brodie, 1996, Brodie, 2005, McCallum and Walsh, 1996, Brodie, and Stansbury, 2007).

Survey coverage, within Hawke Channel + Div. 3K (SFA 6), has been extensive in areas where shrimp occur and reliable estimates of distribution, abundance and biomass have been obtained each year. Farther north, DFO multi-species survey coverage has not been sufficient to resolve the highly patchy distribution of shrimp. During 1999, it was decided that 2G would no longer be surveyed and that future surveys would extend to northern limit of 2H in alternate years. During intervening years, the survey would extend to northern limit of 2J. NAFO Div. 2J3K were surveyed during 2002. However, due to vessel problems, most of 2J and parts of 3K were surveyed during the first two weeks of January 2003 rather than October 2002. Due to recurring vessel problems, 2H was dropped from the 2003 survey. This portion of the survey was completed during 2004. All inshore and offshore strata were surveyed within NAFO Div. 2HJ3K during 2004. The 2005 survey extended to northern limit of 2J. Due to vessel problems, both the 2004 and 2005 surveys were completed during January of 2005 and 2006 respectively. All strata within SFA 5 were surveyed during 2006 and 2008. Since 2009, SFA 5 has been surveyed in its entirety.

The Northern Shrimp Research Foundation (NSRF) in partnership with the Department of Fisheries and Oceans (DFO) conducted a shrimp based research survey into Div. 2G (SFA 4) during the summers of 2005-11 using the Cape Ballard. In 2012, the Aqviq was used after the Cape Ballard became unserviceable. In all years, the NSRF-DFO survey used a Campelen 1800 shrimp trawl and made use of protocols similar to those used by the multi-species when surveying SFA's 5-6. The NSRF-DFO survey focused upon shrimp with sets allocated to depths between 100 and 750 m. The 2G allocation plan had a minimum target of at least 1 set per 250 sq. Nmi. This provided similar coverage to the 1997 and 1999 DFO surveys in 2G.

Since 2003, shrimp species and maturity stage identifications, as well as length frequency determinations have been made at sea, whenever possible. Otherwise, shrimp were frozen and

returned to the Northwest Atlantic Fisheries Centre where identification to species and maturity stage was made. Shrimp maturity was defined by the following five stages:

- males;
- transitionals;
- primiparous females;
- ovigerous females,
- and multiparous females

as defined by Ramussen (1953), Allen (1959) and McCrary (1971). Oblique carapace lengths (0.1 mm) were recorded while number and weight per set were estimated from the sampling data. Inshore strata were not sampled in all years; therefore, the analysis was restricted to data collected from offshore strata only. Total biomass, abundance and length frequency estimates were determined using OGive MAPping calculations (Evans et al. 2000). Over a number of years, carapace lengths and live weights of *Pandalus borealis* were measured within 24 hours of capture. Lengths and weights were converted to natural log values, and regression models were developed for males, transitionals, ovigerous and non-ovigerous females.

Modal analysis using Mix 3.1A (MacDonald and Pitcher, 1979) was conducted on male research length frequencies. Two recruitment indices were estimated from these population estimates. In the first case, the population estimate of age 2 animals provided a recruitment index. In the second case, recruitment was estimated as the population estimates of all males and females with 11.5-17 mm carapace lengths.

Fishable biomass was determined as the weight of males and females with carapace lengths greater than 17 mm. Fishable biomass was determined by converting abundances at length to weight using the models:

Autumn samples

Male shrimp: $Wt(g) = 0.00088*lt(mm)^{2.857}$

Female shrimp: $Wt(g) = 0.00193*lt(mm)^{2.663}$

The fishable biomass index was used in regression analyses, with various lags, against the recruitment indices to determine whether there was improvement in recruit – stock relationship. Such relationships could be used to predict stock prospects.

Exploitation indices were developed by dividing total catch by fishable biomass from the previous autumn survey in SFAs 5 and 6. Because the NSRF-DFO Northern Shrimp survey in SFA 4 is conducted during July, the exploitation rate for this SFA is determined by dividing total catch by fishable biomass for that year.

Spawning stock biomass (total biomass derived from transitionals, primiparous females and ovigerous + multiparous females) was determined via Ogmap calculations.

All indices (biomass, abundance, fishable biomass, female biomass (SSB), recruitment) as well as population adjusted shrimp carapace length frequencies were calculated using Ogmap (Evans et al. 2000).

Instantaneous mortality rate indices

The instantaneous rate of mortality (Z) was determined using various methods. The first method was by plotting the natural logarithm of abundance at each age against age to create catch curves (Ricker, 1975). The peak of the catch curves demonstrated that Northern Shrimp were

fully recruited to the Campelen survey trawl at age 4. The second method was by estimating the survival of age 4+ males and total female abundances were compared with the surviving age 5 + males and total female abundances in succeeding years as follows:

$N_1/N_o = e\text{-}Z$

$Z = -\log_e(1\text{-}A)$

Where N_o = four year running average index for autumn age 4+ shrimp

N_1 = four year running average index for autumn age 5+ and female

shrimp the following year.

Z = instantaneous mortality rate

A = annual mortality rate (Ricker 1975).

Mortality estimates were smoothed by combining 4 years of data in order to account for vagaries within the survey data and due to errors in aging by modal analysis.

Similarly, an index of female mortality was derived as the count of multiparous females measured per set in one year divided by the count of all females (transitionals + primiparous + multiparous) measured per set from the previous year. Data came from the observer dataset within the time period June-July of each year because this is the only time period in which the shrimp are non-ovigerous. It is necessary to conduct this type of mortality estimate when the females are non-ovigerous because it is impossible to detect whether ovigerous females are first or multi-year spawners.

OGive mAPping (ogmap)

OGive MAPping was developed by Dr. G. Evans (DFO–NL Region) to calculate abundance and biomass indices, and population adjusted length frequencies. The method described within Evans (2000) and Evans et al. (2000) assumes that:

- trawl sets are independent random samples from the probability distributions at set locations; and
- nearby distributions are related.

As a first step in the exercise, a dense set of Delauney triangles of known position and depth were developed from the 1995 to 2002 autumn surveys. Catch information was then used to determine the appropriate horizontal and vertical steps used by Ogmap in weighting values according to distances (horizontal and vertical) from each sample location. Points closer to the sample location receive higher weights. Step determination is described in Evans et al. (2000). The appropriate horizontal and vertical steps for the present set of analyses were 30.81 km and .99 m respectively.

Ogmap is then used to compute the expected value of the distribution at every vertex in each Delauney triangle. The expected value within each triangle is integrated using bilinear interpolation. The expected biomass is the sum over all triangles. A Monte Carlo simulation resamples the whole probability distribution at every survey point to provide a new biomass point estimate. Five hundred such simulations are run to provide a probability distribution for the estimated biomass. The point estimate is provided from the entire survey dataset, while the probability distribution is determined through Monte Carlo simulation. Non-parametric 95 % percent confidence intervals are then read from the probability distribution. Conversations with Dr. Evans indicated a discrepancy between calculations used to standardize input data and the calculations used within Ogmap. All indices were multiplied by 1.0068 to correct for this

discrepancy. For this reason there may be a slight difference between indices reported here and those reported in previous assessments.

The Precautionary Approach (PA) framework was applied using an Upper Stock Reference (USR = 80 % of the geometric mean of SSB over a productive period) and a Limit Reference Point (LRP = 30 % of the geometric mean of SSB over a productive period) superimposed upon the exploitation rate trajectory over time. Due to differences in survey history, the respective productive time periods were thought to be 1996-2003 for SFA 6, 1996-2001 for SFA 5 and 2005-09 for SFA 4.

RESULTS

SFA 6 (HAWKE CHANNEL AND NAFO DIVISION 3K)

Commercial fishery

Catches increased from about 3,500 t in 1987 to more than 11,600 t in 1988 and ranged between 6,700 and 11,700 t from 1989 to 1993 inclusive. Annual TACs for SFA 6 in the 1994-96 Integrated Fisheries Management Plan (IFMP, (DFO 2010)) were set at 11,050 t and catches increased to 11,000 t. The TAC for 1997, the first year of the 1997-99 multi-year IFMP, was raised to 23,100 t as a first step toward increasing exploitation within a healthy resource. Most of the increase was reserved for the development of a small vessel component. Catches in 1997 were estimated to be approximately 21,000 t, about 6,100 t were caught by vessels less than 100 feet in length. Despite the large increase in catch, relative exploitation in 1997 remained low and the TAC for 1998 was increased again by 100 % to 46,200 t. Catches exceeded 46,300 t with the expanding small vessel fleet reporting about 30,100 t. The 1999 TAC was increased (27 %) to 58,632 t. Due to operational problems, small vessel catches were 7,400 t short of their 41,029 t TAC, whereas the large vessel fleet took its 17,600 t allocation. In 2000, the TAC was increased by 5 % to 61,632 t. Approximately 63,000 t were taken, 20,000 t by large vessels and 42,600 t by small vessels. The 2001 TAC remained at 61,632 t, of which 19,900 t were taken by the large vessel fleet while only 32,700 t were taken by the small vessel fleet (Tables 1, 2 and 5; Fig. 3). The small vessel fleet did not take its entire quota because shrimp were relatively small, and there was an international glut in the market for peeled, frozen shrimp. This led to a short industry imposed closure throughout July-August, 2001. The closure was also induced by seasonal variances in shrimp yield. On average, yield drops by 5 % over the summer period (A. O'Rielly, pers. comm. NL. Dept. Fish. Aquacult.). The plants and fishermen had to re-negotiate the price structure to account for the seasonal loss in yield. Therefore, plants and fishermen agreed to a small vessel closure, which began on July 1, 2001. Negotiations were completed by September 24 and the fishery reopened with an agreement to harvest no more than 25 million lbs. during the fall, 2001. It is worth noting that the closure did not affect operations at the Charlottetown, Lab. plant which continued to purchase shrimp from 2J fishers because the season is shorter in the north. A second industry imposed closure occurred in August of 2002, again with continued operations at Charlottetown. Once again this was primarily due to low shrimp yield during the summer months.

The TAC remained at 61,632 t during 2002 but further increased, by 26 %, to 77,932 t in 2003. An additional interim quota of 7,653 t was set for the fishing season January 1-March 31, 2004 to facilitate an industry requested change in fishing season from a calendar year (January 1-December 31) to a fiscal year (April 1-March 31 of the next year). Thus the 2003-04 fishing season was 15 months long and had an 85,585 t TAC. Prices had been negotiated prior to the 2003 season and industry had developed a management plan requiring trip limits to be

reduced from 55,000 lbs. during the spring to 38,000 lbs. throughout July and 35,000 lbs. for August. Additionally, shrimp prices dropped significantly over this period to account for the loss in yield (A. O'Rielly, pers. comm. NL Dept. Fish. Aquacult.). Changes in seasonality of the fishery, in price, and trip limits are expected to influence future CPUE model estimates. The 2004-05 fishing season was 12 months and had a 77,932 t TAC. The TAC remained the same through to the 2007-08 management year and the total catch of 80,700 t was taken. The TAC was increased by 9 % to 85,725 t in 2008-09 and maintained at that level until 2009-10. Catches decreased to 75,000 t in 2008-09 and further to 45,100 t in 2009-10. These decreases in catch were mainly due to commercial/ operational factors (Tables 1 and 2; Fig. 2 and 3). Under the IFMP PA framework, the SFA 6 TAC was decreased by 28 % to 61,632 t resulting in an overall TAC of 96,252 t for the 2010-11 management year. Resource status declined further in 2010-11 therefore the SFA 6 TAC was reduced by 15 % to 52,387 t resulting in an overall TAC of 87,007 t for the 2011-12 management year. Resource status in SFA 6 improved in 2011, therefore, the 2012-13 SFA 6 TAC was increased to 60,245 t; resource indices remained high in SFA 4 therefore the TAC in SFA 4 was increased to 13,018 t resulting in an overall TAC of 96,563 t for the 2012-13 management year. It was anticipated that this TAC will be taken by March 31, 2013.

Large vessels primarily fish during the first six months of the year while small vessels fish primarily during the summer months (Fig. 4).

The large vessel fleet fished along the shelf edge during the early 1990's. The fishery extended as far south as the St. Anthony Basin and Funk Island Deep because of the establishment of exploratory areas on the shelf slope in 1992 and 1993, and the discovery of dense concentrations of shrimp within these areas. Assessments at that time suggested there was no reason to divide SFA 6 into separate management units. Therefore, the 1994-96 management plan allowed flexibility to fish anywhere within the combined management area. As a result catch and effort shifted away from the St. Anthony Basin and Funk Island Deep areas. Over the years, the large vessel fleet has taken most of their catch from the entrance to Hawke and Funk Island Deep Channels (Figs. 5-7). The small vessel fishery covers vast areas of SFA 6 with concentrations along the 500 m contour in northern 2J, St. Anthony Basin, as well as, southeastern 3K (Figs. 8-10).

During September 2002, a 400 Nmi square area within Hawke Channel was closed to all but snow crab fishing. The next year, the closed area was expanded to 2500 square Nmi. Then during 2005, the Funk Island Deep box was closed to bottom trawling.

Catch per unit effort (CPUE): two catch rate models were created for the large vessel fleet fishing in SFA 6 over the period 1989–2012. The original model made use of the 2011 formulation in which gear (single + double trawl), year, month, area were the analysis variables using Observer data (calendar year data, no windows, history>3 years.) standardized to 2012 catch rates. The proposed model made use of the original formulation but was standardized to 1989 catch rates and the data were converted to management year data after 2002. Each SFA was broken into boxes (Fig. 11) so that spatial distribution of the fishery could be included as class variables..

According to the original model, catch rates increased steadily from 1989 to 1997 fluctuated at a high level until 2006 after which they decreased to 2009 but have since increased (Table 3; Fig. 12). The model accounts for approximately 72 % of the variance in the data. The original model indicated that 1995, 1996, 1998-2005, 2007 and 2008 catch rates were similar to the 2012 catch rate ($P>0.05$), the 1997 and 2006 values were significantly higher than the 2012 value ($P<0.05$) while all other values were significantly lower. Figure 13 provides a comparison between

original and proposed model CPUEs. Figure 14 clearly indicates that there are no trends in the scatter of residuals around the parameter estimates within the original model.

The fact that the CPUE increased significantly over the 1992–95 period and thereafter remained high would suggest two regimes within the shrimp population, with an inflection point during the mid-1990's.

The proposed model accounted for 72 % of the variance in the data. All catch rates were significantly higher than the 1989 ($P<0.005$) estimate (Table 4; Fig. 15). Figure 16 clearly indicates that there are no trends in the scatter of residuals around the parameter estimates. The proposed model was accepted by the peer review.

Table 5 and figure 17 provide the small vessel CPUE model output (logbook data; history >3 years, size class, month area) while figure 18 provides a graphical representation of the model. The model accounted for 67 % of the variance in the data, with 1999, 2002 and 2003 catch rate values being similar to the 1998 value. All other catch rate estimates were significantly higher than 1998 values. Figure 19 shows that the large vessel catch rate estimates were similar to the small vessel catch rates for the periods 1999-2003 ($r^2 = 0.87$) and 2004-12 ($r^2 = 0.80$). The two clear bands of relationships within this plot may be due to learning among the small vessels as the small vessel fishery began during 1997 and there were up to 300 small vessels fishing shrimp in any year. Figure 20 indicates the scatter of residuals around estimated parameters. There are no clear trends in the scatter of residuals. The inter-quartile boxes are close to the zero reference lines indicating that there is not a great deal of variation in the data.

Biomass from fishery data: fishery catch per unit effort data were applied to stratified areal expansion techniques with the goal of estimating biomass. This effort had the following assumptions:

- sets could be standardized between years and ships;
- the fishing sets within each strata would be treated as being random and independent of each other, and
- the catches are normally distributed.

Table 6 shows the outcome of the stratified analysis using the large vessel catch per unit effort data. This analysis shows certain strata, but not all strata, have been consistently important since 1989. Table 7 shows that most of the commercial fishery takes place in 200–500 m depths. Neither table indicate any obvious signs of resource contraction.

Since all strata were not consistently fished throughout the history of the fishery, it was necessary to re-run the analysis using index strata (Fig. 21). Unfortunately during the first three years of the fishery, there was insufficient data to complete this analysis and therefore the analysis began in 1992. Table 8 provides the biomass estimates from the six consistently fished strata at the mouth of Hawke Channel, at northern edge of St. Anthony Basin and along the 2J3K shelf edge (Figs. 5-7 and 21). Table 9 indicates that most of the shrimp has consistently come from 201 – 400 m depth range with no sign of contraction. In general, biomass remained low (average = 97,000 t) until 1999 then increased to 2002, remaining high since (average = 190,000 t).

Tables 10-13 provide the stratified analyses of small vessel fleet catch data. The biomass estimates from the small vessel index strata increased from 96,000 t in 1998 to 175,000 t in 2007, then dropped to 115,000 t in 2009 and remained near this level since. Figures 5-10 indicate that both the large and small vessel fleets fished in the north eastern part of SFA 6 along the slope edge and near the mouth of Funk Island Deep, however that is where the similarity ends. The small vessel fleet rarely fished near the mouth of Hawke Channel but

tended to fish over a relatively broad area in 3K. However, certain generalities may be made between the two fleets. These plots and the index stratified analyses indicate that the bulk of both fisheries take place in only a few strata within the 200–500 m depths (Tables 6 and 10). Neither the small nor the large vessel stratified analyses showed signs of contraction.

Size composition: Several length frequency observations were taken from large and small vessel catches (Figs. 23 and 24). Catch at length from samples taken by observers on large vessels consisted of a broad size range of males and females believed to represent more than two year classes. The male modes overlapped to the extent that it was not possible to complete modal analysis; however, the male modes often had three faint sub-peaks implying the presence of more than one year class. Given that the modes were usually near 14 mm, 18 mm and 20 mm, these animals were probably 2-4 years of age respectively. Catch rates for large vessels had been maintained at over 240,000 animals per hour. The within year frequency weighted average carapace lengths for males ranged between 17.26 mm and 18.26 mm, while the weighted average carapace lengths for females ranged between 21.67 mm and 22.64 mm. There were no trends in the average size of either males or females.

Catch rates for small vessels had been maintained at over 55,000 animals per hour. The within year frequency weighted average carapace lengths for non-ovigerous shrimp ranged between 18.4 mm and 19.94 mm, while the weighted average carapace length for ovigerous females ranged between 21.90 mm and 23.15 mm. There was no trend in the weighted average size of either ovigerous or non ovigerous shrimp in the small vessel catch.

Research survey data

Stock size: Inshore strata along the northeast Newfoundland coast were not sampled during either 1995 or 1999. Due to weather conditions, it was not possible to survey the 3K inshore strata during 2007. Therefore for comparative purposes, the analyses were confined to the offshore strata. Inshore areas, sampled during other surveys, generally produced low catches of shrimp that did not contribute substantially to the biomass/abundance estimates. Additionally, it is important to note that there is uncertainty around the 2002-05 surveys because, due to vessel problems, they were finished in January or early February rather than during December as planned.

Figure 25 shows that the shrimp have been broadly distributed within SFA 6 and that bottom water temperatures have warmed between 1996 and 2011 but cooled again during 2012.

Figure 26 provides the Delauney triangulation file used in the SFA 6 Ogive Mapping (Ogmap) analyses.

Figure 27 and table 14 indicate that total biomass increased by 108 % from 429,000 t (96 billion animals) in 1997 to a peak of 895,000 t (208 billion animals) in 2006 before decreasing by 60 % to an all-time low of 360,000 t (83 billion animals) in 2010. Total biomass increased by 34 % to 483,000 t (114 billion animals) in 2011 before declining to 395,000 t (93 billion animals) in 2012.

Fishable biomass index increased from 310,000 t in 1997 to a peak of nearly 670,000 t in 2006 then declined steeply to 295,000 t in 2010, increased to 409,000 t in 2011 before returning to 316,000 t by 2012. The trend in female spawning stock biomass index reflected the trend in the fishable biomass index decreasing to 187,000 t in 2012, which is comparable to the beginning of the time series (Table 15; Fig. 28).

It is noteworthy that the small and large vessel catch rate models indicate that the fishery performance has been increasing since 2009-10 while the research survey shows that the resource declined over the 2006-09 period and remained low since. This discrepancy can be

accounted by the fact that fishers do not fish randomly as per survey protocols. The fishers concentrate upon productive strata while the survey covers a much broader area.

Stock composition: length distributions representing abundance–at–length from the autumn 1996-2012 surveys are compared in figure 29. Modes increase in height as one moves from ages 1-3 indicating that catchability of shrimp in the research trawl probably improves as the shrimp increase in size, as well, there is an accumulation of animals at each length class due to varying but generally reduced growth rates as males become older. Table 16 provides the modal analysis and the estimated demographics from the autumn survey. This time series provides a basis for comparison of relative year-class strength and illustrates changes in stock composition over time. Diagonal blue lines are used to illustrate that strong modes can be linked through as many as four succeeding years. The 1997 year-class first appeared as a clear mode, in the 1998 survey (Fig. 29), at 10.11 mm, as two year old shrimp in the 1999 survey at 15.01 mm, as three year old shrimp in the 2000 survey at 17.51 mm and as four year olds in the 2001 survey at 19.31 mm (Table 16). Similarly, the 1998 year-class could be tracked for four years. The fact that strong year classes could be followed for four years until they became females provides strong evidence that these animals change sex at four years of age.

Even though modal length at age varies between years reflecting different growth rates for the different cohorts, there is a great deal of inter-annual consistency in modal positions and the relative strength of cohorts is maintained from one year to the next (Table 16; Fig. 29). Figure 30 illustrates that shrimp abundance from one cohort can be used to predict abundance in succeeding years (r^2 => 62 %) providing evidence that modal analysis is meaningful. Shrimp aged 2-4 dominated the male component of the length frequencies in 2012 (2011, 2010 and 2009 year-classes) survey with carapace length frequency modes at 14.26, 17.44 and 19.78 mm respectively.

Female length frequency distributions are broad indicating that they probably consist of more than one year-class. However, there is concern because female biomass and abundance indices have been reduced by over 50 % since 2006 (Tables 15 and 16; Figs. 28 and 29).

Recruitment indices: northern shrimp recruitment indices are determined as the abundance of age 2 animals from the modal analysis (MacDonald and Pitcher 1993) of Northern Shrimp Ogmapped length frequencies from research survey data (Tables 16 and 17; Fig. 31), as well as the abundance of all animals with carapace lengths between 11.5 and 17 mm (Table 17; Fig. 31). Recruitment indices have been variable, peaking in 2006, but have since declined to the long term mean (1996–2010) remaining low since. The apparently strong 2004 year class (2006 index) did not lead to increased fishery biomass. The relationship between recruitment and fishable biomass is uncertain. Participants within the meeting agreed that further work will have to be completed to find predictive relationships.

Mortality rates: the descending limb within much of the catch curve analysis begins at age 4 providing strong evidence that Northern Shrimp are not fully recruited to the survey gear until age 4. The median instantaneous mortality was 0.75 while the median survival rate was approximately .5. As demonstrated by the exponential decay graph in the lower right panel, an average annual total mortality of 50 % would allow animals to survival to approximately 6 years of age in agreement with the modal analysis (Fig. 32). However, it must be noted the mortality estimates derived from catch curves are only valid for the ages that are fully recruited to the survey gear. Mortality rates are often much higher for very young and senescent animals than for mid aged animals.

Based upon age 4+ males and females at time zero against age 5+ males and females during the next year, the median survival, annual mortality, and instantaneous mortality rates were 0.59, 0.41 and 0.52 respectively (Table 18). These values appear reasonable as they do not

imply excessively high densities of shrimp necessary to maintain the populations estimated from research surveys. As well these values are similar to those found for the Gulf of St. Lawrence (Frechette and LaBonte 1981). Table 18 and figure 33 indicate that survival has decreased by 27 %, from 0.66 in 2005 to 0.42 by 2012. It must be noted that these survival estimates are lower than a similar table produced from the 2011 assessment because the previous analysis compared age 3+ males and females at time zero against age 4+ males during the next year.

Once a female becomes ovigerous, it is impossible to determine whether she is a first time or multi-year spawner. Therefore, observer data for the months June and July were used in the mortality estimates that compared abundances of primiparous females at time zero against abundances of multiparous females the next year because that was the only period during which very few females are ovigerous. Using this method, median survival, annual mortality, and instantaneous mortality rates were 0.60, 0.40 and 0.50 respectively (Table 19). There were no clear trends in mortality rates using this method (Table 19; Fig. 33). These mortality rates indices may appear high, implying that a large number of females die each year. However, it is reasonable that mortality using this method is slightly higher than it was with the previous method, because it must be very stressful to produce, extrude and then hold eggs. As well, females are the older animals and many may die from senescence. The female mortality rates are within the range of values presented in Shumway (1985), Bergström (2000) and (L. Savard, pers. comm.).

Exploitation rate: in the long term, the exploitation rate index has varied around 15 %. The exploitation rate decreased from 2004/05 to 2009/10 and increased in the following two years (Table 15; Fig. 34). It should be noted that actual exploitation rates are unknown but are likely lower than indicated above because the Ogmap indices are believed to be underestimates (i.e., catchability of shrimp in the survey gear is unknown but believed to be <1).

Precautionary approach: research survey SSB was assessed to be in the Cautious Zone, within the IFMP PA Framework, for the third time in the four most recent years. The 2012-13 exploitation rate is expected to be about 15 %. If the 60,245 t TAC is maintained through 2013-14 and taken the exploitation rate will increase to 19 %; the third highest level in the time series (Fig. 35).

SFA 5 (HOPEDALE AND CARTWRIGHT CHANNELS)

Commercial fishery

Shrimp catches in Hopedale and Cartwright Channels increased from about 2,700 t in 1977 to 4,100 t in 1980, declined to 1,000 t in 1983 and 1984, increased again to 7,800 t in 1988, stabilizing at roughly 6,000 t during the 1989-93 period. TAC's for the 1994-96 management plan, which combined the two channels as a single management area, were increased to 7,650 t annually and catches subsequently increased, averaging 7,500 t during that period. Annual TAC's for the 1997-99 plan were increased by 100 % to 15,300 t and catches were near 15,100 t each year. The 15,300 t TAC (note that 1,530 t was set aside for the small vessel fleet) was maintained in the 2000-02 plan. In 2003, the TAC increased 52 % to 23,300 t. (In 2003, the fishing season changed to April 1-March 31, and an additional interim quota of 9,784 t was set for the period January 1-March 31, 2004. The 2003-04 fishing season was 15 months long and had a 33,084 t TAC. The 2003-04 management year TAC (23,300 t) was maintained for the 2004-05 to 2012-13 seasons. The history of the total fishery within SFA 5 is presented in tables 1 and 2, as well as figure 36. Catches varied between 22,600 t and 25,300 t each year between 2004-05 and 2011-12. Preliminary data indicate that 18,100 t of shrimp were taken from a TAC of 23,300 t during the 2012-13 management year (Tables 1, 2; Fig.36). An allocation has been

available in recent years for small vessels but this fleet sector contributes only in a minor way to the fishery, relative to the large vessel fleet. In later years, the large vessel catches appear to exceed the large vessel quotas because of quota transfers; however, as illustrated in figure 33 the total combined fleet quotas have rarely been exceeded.

Since 1995, the seasonality of the fishery switched from a spring-fall to an all year operation (Fig. 37).

During the late 1970's and throughout the 1980's, the fishery concentrated in four main areas: northern, eastern, and southern Hopedale Channel and Cartwright Channel. Fishing continued in the traditional areas during the 1990's, however, more effort has since been reported from the slopes of the shelf, north and east of Cartwright Channel (Figs 38-40).

Catch per unit effort (CPUE): two CPUE models were produced, an original and a proposed model. The original model made use of single and double trawls, no windows and vessels with at least a three year history in the fishery. This model was standardized to 2012 estimates and made use of calendar year data (Table 20; Figs. 41 and 42). The original model accounted for approximately 77 % of the variance in data. The scatter of residuals around parameter estimates is provided in figure 43. There were no trends in the residuals, for the most part they appear centered around the reference line and the inter-quartile boxes appear to be small indicating a relatively good fit between the model and the data. Table 21 and figure 44 provide the glm output for the proposed SFA 5 large vessel catch rate model. This model differed from the original model by being standardized to the first year and having the data converted to management year. The proposed model accounted for 78 % of the variance in the data. With the exception of 1985, 1992 estimates, the estimates between 1981 and 1994 were similar to 1980 estimates with all others higher (Fig. 44). Catch per unit effort (CPUE) increased from 1992 to 2001 and has oscillated around this higher level since then (Table 21; Figs. 42 and 44). The scatter of residuals around parameter estimates is provided in figure 45. There were no trends in the residuals, for the most part they appear centered around the reference line and the inter-quartile boxes appear to be small indicating a relatively good fit between the model and the data.

Biomass from fishery data: As in SFA 6, the stratified analysis of large vessel commercial catch data indicates all strata are not consistently occupied throughout the history of the fishery, that important strata appear to remain important through much of the history (Table 22). The important commercial depths range between 200-400 m (Tables 22–25). Figure 46 indicates the index strata consistently fished by the large vessel fleet and used in the stratified areal expansion calculations presented in table 24. Tables 22-25 showed no signs of resource contraction.

Stock composition: due to the overlap of modes, it was not possible to complete modal analysis on the commercial length frequencies. Male and female length frequency distributions are broad indicating that each probably consists of more than one year class (Fig. 47). Catch rates have been maintained at more than 460,000 animals per hour. The within year frequency weighted average carapace lengths for males ranged between 18.04 mm and 19.30 mm, while the weighted average carapace lengths for females ranged between 21.90 mm and 22.93 mm. There were no trends in the average size of either males or females.

Research survey data

Stock size: annual multi-species surveys were conducted throughout the entire of SFA 5 (Cartwright + Hopedale Channels) between 1996 and 1999. SFA 5 was surveyed in its entirety in only four (2001, 2004, 2006, 2008) between 2000 and 2009 but has been surveyed in its entirety since. Figure 48 shows that bottom temperatures warmed from 1996 to 2011 but have

since cooled. Figure 49 provides the SFA 5 Delauney triangulations used in the Ogive Mapping calculations of survey indices.

Biomass within the entire of SFA 5 increased by 190 % from 86,000 t (17 billion animals) in 1998 to 249,300 t (62 billion animals) during 2001, then decreased by 25 % to 186,000 t (40 billion animals) by 2004, remaining near that level through to 2012 (Table 26; Fig. 50). A comparison between Figs. 25 and 27 with 48 and 50 demonstrates that the distribution of animals is more widespread and evenly dispersed within SFA 6 than it is in SFA 5 because the 95 % confidence intervals are tighter among SFA 6 estimates relative to SFA 5 estimates. The fact that shrimp are highly concentrated in two main channels and along the shelf edge within SFA 5 accounts for the broad confidence limits around the research survey point estimates. The SFA 5 fishery takes place in areas of high research catches (Figs. 2 and 38-40).

Fishable biomass index increased from around 90,000 t in 1996-99 to 184,000 t in 2001. The index has been around 150,000 t from 2004 onward. The 2012 estimate was 147,000 t (Table 27; Fig. 51). Female spawning stock index increased from 40,000 t in the 1996-99 period to 96,000 t in 2001 and has since decreased. The 2012 estimate is 63,000 t (Table 27; Fig. 52).

Figure 53 presents the Northern Shrimp research survey length frequencies. No modal analysis was attempted as clear modes were not always evident due to slow growth relative to that in more southerly SFAs. The solid red and green lines show that the 2012 autumn length frequencies were near the long term average.Recruitment indices: recruitment oscillated along the long term mean over the time series (Table 28; Fig. 54). Recruitment prospects are uncertain because there is no apparent relationship between available indices and subsequent SSB.

Mortality rate: annual female total mortality oscillated between about 35-75 % over the period 1998-2011 averaging about 60 % (Table 29; Fig. 55).

Exploitation rates: exploitation rate indices ($catch_{year}$/fishable $biomass_{previous\ year}$) varied without trend around 15 % over most of the time series (Table 27; Fig. 56).

Precautionary approach: research survey SSB was assessed to be in the Healthy Zone within the IFMP PA Framework. The 2012/13 exploitation rate is expected to be about 16 %. If the 23,300 t TAC is maintained through 2013/14 and taken then the exploitation rate will remain at 16 % (Fig. 57).

SFA 4 (NAFO DIVISION 2G)

Commercial fishery

Total allowable catches increased from 2,580 t in 1989 to 5,200 t in 1995 and 8,320 t in 1998 (Table 1; Fig. 58). The 1998 TAC allocated 2,184 t to the area south of 60° N to promote spatial expansion of the fishery. The 2003 TAC was increased to 10,320 t. In 2003 the management year changed to April 1–March 31, and an additional interim quota of 2,802 t was set for the period January 1–March 31, 2004. Thus the 2003-04 management period was 15 months and had a 13,122 t TAC. The 2003-04 management year TAC (10,320 t) was maintained through to 2008-09 then increased to 11,320 t for the 2008-09 to 2011-12 management years. The Canadian Atlantic Quota report indicates indicate that 10,500 t were taken in each of these management years. The TAC was increased to 13,018 t for the 2012-13 management year and preliminary data indicate that this quota was taken (Tables 1 and 2; Fig. 58).

The seasonality of the fishery has changed greatly over the years as ice conditions changed. Prior to 2002, the fishery occurred during the spring and summer. After 2001, the fishery switched to summer fall fishery with an increased amount of fishing during the winter (Fig. 59).

The large vessel fleet fishes along the northeastern shelf edge in depths as great as 700 m, in Ogak Channel and to a lesser degree along the southern shelf edge (Figs. 60 - 62).

Catch per unit effort (CPUE): two CPUE models were produced, an original and a proposed model. The original model made use of single and double trawls, no windows, all months, all areas and vessels with at least a three year history in the fishery (Table 30; Figs. 58 and 64). The original model was standardized against 2012 calendar year estimates. The original model accounted for approximately 62 % of the variance in the data. The catch rates oscillated with 1991, 1993, 1994, 1997-2000, 2002, 2003, 2006-08 values statistically similar to 2012 values which was approximately average over the time period (Table 30; Figs. 63 and 64). The scatter of residuals around parameter estimates is provided in figure 65. There were no trends in the residuals, for the most part they appear centered around the reference line and the inter-quartile boxes appear to be small indicating a relatively good fit between the model and the data.

The proposed model accounted for 61 % of the variance in the data and was similar to the original model except that data were converted to management year and the model was standardized to 1989 values. The 1989 catch rate index was similar to the 1995 and 1996 ($P > 0.05$) but significantly lower than all other values (Table 31; Figs. 64 and 66). The scatter of residuals around parameter estimates is provided in figure 67. There were no trends in the residuals, for the most part they appear centered around the reference line and the inter-quartile boxes appear to be small indicating a relatively good fit between the model and the data.

Meeting participants agreed that there were several confounding influences that affect catch rates in this area. These include:

- changes in management decisions:
- In 1998, 2,184 t of the TAC was allocated to the area south of 60°N to promote spatial expansion of the fishery. By 2009-10, the regulations were changed such that the vessels no longer had to fish a portion of their catch in southern SFA 4.
- changes in seasonality:
- Prior to 2002, the fishery occurred during the spring and summer. After 2001, the fishery switched to summer fall fishery with an increased amount of fishing during the winter.
- changes in fishing pattern due to searching:
- At various meetings, fishers indicated that some years there may have been more searching along the Labrador shelf edge. Searching may have extended into the shallower water.
- changes in market conditions:
- Northern and striped shrimp (*Pandalus montagui*) are now similar in value therefore fishers are no longer trying to avoid areas of high *P. montagui* concentrations.

For these reasons, it was felt that CPUE had limited value as a tool to monitor fishery performance.

Size composition: Catch-at-length data for the 2003-04-12-13 period showed variable size distributions between years (Fig. 68). Catch at length from the observer large vessel dataset consisted of a broad size range of males and females believed to represent more than two year classes. As with the more southern shrimp fishing areas, the modes were highly overlapping

therefore it was not possible to age either males or females using modal analysis. Catch rates for large vessels had been maintained at over 278,000 animals per hour. The within year frequency weighted average carapace lengths for males ranged between 18.26 mm and 20.49 mm while the weighted average carapace lengths for females ranged between 22.57 mm and 24.48 mm. There was no trend in the average carapace length for either sex.

Biomass from fishery data: as with the SFAs further south, the stratified analysis of large vessel commercial catch data indicates that not all strata are consistently occupied throughout the history of the fishery and that important strata appear to remain important through much of the history (Table 32). The important commercial depths range between less than 200 m to 400 m which is shallower than in the more southerly SFAs (Table 33). There was no analysis using index strata as there were only two strata that were consistently fished over time.

Research survey data

Stock size: since 2005, eight annual July shrimp surveys have been conducted in NAFO Div. 2G. These surveys have been conducted jointly by the Northern Shrimp Research Foundation (NSRF) and DFO. Figure 69 presents the NSRF-DFO research survey catches over the 2006-12 surveys overlain with bottom temperatures. As with the more southerly SFAs, temperatures increased to 2011 but have since decreased.

Figure 70 presents the Deluaney triangulation file used in Ogive Mapping calculations.

The M.V. Cape Ballard was used as the research platform over the 2005-11 period. However, during 2012 this ship became unserviceable and was replaced by the M.V. Aqviq. Dr. Steve Walsh wrote a report indicating that the change in vessels should have little impact upon research catch therefore there was no comparative fishing exercise between the two vessels. Total biomass increased from 71,000 t (14 billion animals) in 2005 to 205,200 t (42 billion animals) in 2009, decreased to 146,000 t (31 billion animals) in 2010, remained near that level in 2011 before increasing to 214,100 t (45 billion animals) in 2012. This was the highest total biomass in the time series (Table 34; Fig. 71). Discussions during the meeting indicated that the Captain may not have followed the assigned fishing protocols. Post survey analyses indicated that warp lengths were shorter than during previous surveys. The shorter warp lengths resulted in decreased wing spreads which would have been accounted for the in the standardization procedures. However, it was noted that the shorter warps may have also resulted in greater door stability which may have impacted fishing performance. Stratified analyses of research survey total biomass indicate that most of the biomass is found in the 200-300 m depth range (Tables 35 and 36).

Fishable biomass index increased from 62,000 t in 2005 to 180,000 t by 2009, decreased to 127,000 t in the next year before increasing to 191,000 t in 2012. Similarly, the female spawning stock biomass (SSB) index increased from 35,000 t in 2005 to 140,000 t by 2009, decreased to 71,000 t in 2010 then increased to 110,000 t in 2012 (Table 37; Fig. 72).

Figure 73 presents the Northern Shrimp research survey length frequencies. No modal analysis was attempted as clear modes were not always evident due to slow growth relative to that in more southerly SFAs. The solid red and green lines show that the 2012 autumn length frequencies were above the long term average.

Recruitment indices: recruitment increased from 1.8 billion animals in 2005 to 8.3 billion in 2009 then decreased slightly to 4.6 billion animals by 2011 before increasing to 6,100 billion animals by 2012 (Table 38; Fig. 74). As one moves north from 3L toward 2G, the recruitment signal becomes less clear, because the abundances of animals decrease from south to north resulting in relatively high numbers of small animals filtering through the 40 mm mesh ahead of

the codend (Figs. 28, 53 and 75). As numbers decrease, the amount of clogging of the net, by shrimp and other organisms, decreases resulting a greater loss of small shrimp through the large mesh ahead of the codend. For this reason, a small mesh (12.7 mm knot to knot) juvenile shrimp net is attached slightly ahead of the codend. Figure 75 clearly indicates modes from 0-group (8-9 mm carapace length) and one year (12-13 mm carapace length) old animals may be tracked from one year to the next in the juvenile shrimp net samples. These modes are not always evident in the codend samples. The first clear mode, found in the codend, is at 15 mm and is thought to be from three year old animals. It is hoped that over time, information gathered from the juvenile shrimp net samples can be used as an aid in ageing the SFA 4 shrimp. Juvenile shrimp net samples may provide a reliable recruitment index, in the future. As with SFAs further to the south, recruitment prospects are uncertain because there is no apparent relationship between available indices and subsequent SSB.

Mortality: annual female total mortality oscillated between about 40-50 % over the period 1999-2008 (Table 39; Fig. 76). There are no estimates available since then due to high proportion of ovigerous females in the commercial catch.

Exploitation rate: exploitation rate has been between 6 and 9 % since 2007/08 and the current estimate is 7 % (Table 37; Fig. 77).

Precautionary approach: research survey SSB index was assessed to be in the Healthy Zone, within the IFMP PA Framework, and it is anticipated that the 2012/13 exploitation rate will be less than 10 % (Fig. 78) once catch reporting is complete.

SOURCES OF UNCERTAINTY

The implications of finishing some autumn multi-species surveys later than usual are unknown.

Spatio-temporal variation among three DFO research vessels particularly in NAFO Div. 3K (SFA 6) is a source of uncertainty and the implications are unknown.

The survey in SFA 4 had been conducted by the Cape Ballard from 2005 to 2011. In 2012, the Aqviq was used after the Cape Ballard became unserviceable. Following the survey it was determined that the survey protocol was not followed in that the warp ratio was shortened. No inter-calibration was conducted. These changes may have affected trawl performance and it is unknown what effect they had on the survey results.

The shortness of the survey time series, lack of dynamic range and stock-recruit relationships limits modeling stock dynamics. There is no risk analysis for this resource. There is uncertainty in the appropriateness of the current reference points as it is unknown how the survey biomass relates to B_{MSY}.

The current management areas may not represent biological units. Causes in one management area may produce effects in other management areas.

Trawls used in the surveys have shrimp catchability less than one but the exact value is unknown. Therefore, the survey underestimates biomass. Catch is known; however, the total fishery-induced mortality is unknown (landed catch plus incidental mortality from trawling). Exploitation rates are a relative index rather than absolute.

Physical changes in the environment may affect the availability of shrimp to commercial and survey trawls.

It should be noted that actual exploitation rates are unknown but are likely lower than indicated above because the Ogmap indices are believed to be underestimates (i.e., catchability of shrimp in the survey gear is unknown but believed to be <1).

CONCLUSIONS

SFA 6

There is concern for the current status. The trend in female spawning stock biomass index reflected the trend in the fishable biomass index decreasing to 187,000 t in 2012, which is comparable to the beginning of the time series. The SSB is in the Cautious Zone of the IFMP PA framework for the third time in the four most recent years.

Total annual mortality increased from 34 % to 58 % after 2001. If the 60,245 t TAC is maintained through 2013-14 and taken the exploitation rate will increase to 19 %, the third highest level in the time series.

SFA 5

Current status remains positive. Fishable biomass index increased from around 90,000 t in 1996-99 to 184,000 t in 2001. The index has been around 150,000 t from 2004 onward. The 2012 estimate is 147,000 t. SSB index increased from 40,000 t in the 1996-99 period to 96,000 t in 2001 and has since decreased. The 2012 estimate is 63,000 t. SSB is in the Healthy Zone of the IFMP PA framework and if the current TAC is taken in 2013-14, the exploitation rate index would remain at 16 %.

SFA 4

Current status remains positive. Biomass indices are at or near their highest levels over the short time series. The exploitation rate has been between 6 and 9 % since 2006-07. SSB index was assessed to be in the Healthy Zone, within the IFMP PA Framework, and it is anticipated that the 2012-13 exploitation rate will be less than 10 %.

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Table 1. Total Allowable Catches (t) of Northern shrimp (Pandalus borealis) by Shrimp Fishing Area (SFA), 1978-2012/13

Year	DIV. 2G SFA 4	HOPE SFA 5	CART SFA 5	HAWKE SFA 6	DIV. 3K SFA 6	TOTAL
1978	500	4,500	800	800	500	7,100
1979	500	3,200	800	1,750	500	6,750
1980	500	4,000	800	850	500	6,650
1981	500	4,000	800	850	500	6,650
1982	500	4,000	800	850	500	6,650
1983	500	4,000	800	850	500	6,650
1984	500	3,500	700	850	500	6,050
1985	500	2,800	770	850	500	5,420
1986	500	3,400	1,000	850	1,200	6,950
1987	500	4,000	800	1,500	1,500	8,300
1988	500	4,000	800	1,500	1,500	8,300
1989	2,580	4,400	1,600	2,000	3,600	14,180
1990	2,580	4,400	1,600	2,000	3,600	14,180
1991	2,635	4,760	1,615	2,210	2,091	13,311
1992	2,635	4,760	1,615	3,910	3,655	16,575
1993	2,735	4,760	1,615	3,846	5,334	18,290
1994	4,000	7,650		11,050		22,700
1995	5,200	7,650		11,050		23,900
1996	5,200	7,650		11,050		23,900
1997	5,200	15,300		23,100		43,600
1998	8,320	15,300		46,200		69,820
1999	8,320	15,300		58,632		82,252
2000	8,320	15,300		61,632		85,252
2001	8,359	15,300		61,623		85,282
2002	8,320	15,300		61,632		85,252
2003/04	13,122**	33,084**		85,575**		131,781
2004/05	10,320	23,300		77,932		111,552
2005/06	10,330	23,300		77,932		111,562
2006/07	10,320	23,300		77,932		111,552
2007/08	10,320	23,300		77,932		111,552
2008/09	11,320	23,300		85,725		120,345
2009/10	11,320	23,300		85,725		120,345
2010/11	11,320	23,300		61,632		96,252
2011/12	11,320	23,300		52,387		87,007
2012/13	13,018	23,300		60,245		96,563

**The offshore licence holders requested that their quotas starting in 2003 run from April 1-March 31 rather than January 1-December 31, therefore the increased quotas for 2003 reflect the amount of shrimp that would have been caught under the December-January schedule. Please note that the quotas do not include quota transfers or bridging between years.

Table 2. Nominal catches (t) of Northern shrimp (Pandalus borealis) by Shrimp Fishing Area (SFA), 1977-2012/13.

Year	DIV. 2G SFA 4	HOPE SFA 5	CART SFA 5	HAWKE SFA 6	DIV. 3K SFA 6	TOTAL
1977	-	1,272	1,414	<1	<1	2,686
1978	-	2,109	1,521	-	-	3,630
1979	3	2,693	1,034	5	-	3,735
1980	<1	3,938	170	-	-	4,108
1981	2	3,382	67	135	-	3,586
1982	5	1,829	154	<1	-	1,988
1983	30	997	3	-	-	1,030
1984	-	712	290	-	-	1,002
1985	-	1,687	2	-	-	1,689
1986	2	3,498	1,328	-	-	4,828
1987	7	4,538	1,418	1,678	1,845	7,808
1988	1,083	6,584	1,254	3,747	7,849	16,770
1989	3,842	4,329	1,656	1,855	6,662	16,489
1990	2,945	3,769	1,591	1,929	5,598	13,903
1991	2,561	4,501	1,617	1,976	5,500	14,179
1992	2,706	4,680	1,635	3,015	6,609	15,630
1993	2,723	4,273	1,446	3,672	8,035	16,477
1994	3,982	7,499		10,978		22,459
1995	5,104	7,616		10,914		23,634
1996	5,160	7,383		10,923		23,466
1997	5,216	15,103		21,018		41,337
1998	8,051	15,170		46,337		69,558
1999	7,884	15,109		51,202		74,195
2000	7,382	14,694		63,224		85,300
2001	8,117	15,116		52,590		75,822
2002	8,387	15,339		60,384		84,110
2003/04**	13,020	30,437		71,227		114,684
2004/05	9,644	24,033		77,776		111,453
2005/06	10,247	22,904		74,728		107,878
2006/07	10,084	22,612		75,673		108,369
2007/08	10,009	23,768		80,725		114,502
2008/09	9,682	20,503		74,505		104,691
2009/10	10,656	25,094		45,527		81,277
2010/11	11,134	21,425		61,501		94,060
2011/12	10,441	25,264		59,685		95,390
2012/13	13,148	18,070		51,049		82,267

**In 2003, the offshore licence holders were allowed to change their quota period from January 1–December 31 to April 1–March 31. The 2012/13 values as of January 28, 2013.

Table 3. Original multiplicative specification for large vessel Northern Shrimp catch per unit effort (CPUE) model for SFA 6, 1989-2012-13. (single + double trawl, observer data, no windows, history > 3 years, standardized to 2012-13 values).

Year	Percent Catch in model	CPUE Relative to 2013	Standardized Modelled CPUE	Effort (HRS)
1978	-	-	-	-
1979	-	-	-	-
1980	-	-	-	-
1981	-	-	-	-
1982	-	-	-	-
1983	-	-	-	-
1984	-	-	-	-
1985	-	-	-	-
1986	-	-	-	-
1987	-	-	-	-
1988	-	-	-	-
1989	17	0.21	317	21,026
1990	41	0.27	404	13,858
1991	78	0.38	568	9,691
1992	61	0.42	617	10,708
1993	81	0.50	737	10,897
1994	97	0.69	1,018	10,788
1995	101	0.92	1,367	7,987
1996	102	0.98	1,458	7,494
1997	79	1.13	1,668	8,967
1998	86	0.98	1,451	11,211
1999	96	0.96	1,415	12,432
2000	101	1.09	1,609	12,446
2001	98	1.10	1,622	12,272
2002	85	0.94	1,386	14,809
2003/04	57	0.96	1,419	20,705
2004/05	77	1.01	1,498	16,331
2005/06	104	1.02	1,510	16,549
2006/07	102	1.14	1,691	14,703
2007/08	109	1.06	1,563	17,603
2008/09	115	1.01	1,497	11,183
2009/10	73	0.76	1,130	16,485
2010/11	146	0.90	1,326	15,367
2011/12	85	0.83	1,226	19,131
2012/13	163	1.00	1,480	6,923

TAC's from 1987 to 1990, inclusive are for the fishing season May 1 to April 30, making 1986 a16 month year (January 1 1986-April 30, 1987).Effort calculated as catch/ CPUE. During 2003, there was an industry requested change in fishing season from January 1-December 31 to April 1- March 31,thus there was a season roll-over making the 2003 March 2004 a 15 month year with a roll-over quota increase of 20,229 t.

Table 4. Proposed multiplicative specification for large vessel Northern Shrimp catch per unit effort (CPUE) model for SFA 6, 1989-2012-13. (single + double trawl, observer data, no windows, history > 3 years, standardized to 2012-13 values).

Year	Percent catch in model	CPUE Relative to 1989	Standardized Modelled CPUE	Effort (HRS)
1978	-	-	-	-
1979	-	-	-	-
1980	-	-	-	-
1981	-	-	-	-
1982	-	-	-	-
1983	-	-	-	-
1984	-	-	-	-
1985	-	-	-	-
1986	-	-	-	-
1987	-	-	-	-
1988	-	-	-	-
1989	17	1.00	308	21,617
1990	41	1.27	393	14,254
1991	78	1.79	553	9,949
1992	61	1.96	603	10,961
1993	81	2.33	719	11,169
1994	97	3.23	994	11,044
1995	101	4.34	1,337	8,166
1996	102	4.63	1,427	7,655
1997	79	5.34	1,647	9,080
1998	86	4.62	1,423	11,432
1999	96	4.50	1,387	12,676
2000	101	5.13	1,581	12,662
2001	98	5.17	1,594	12,485
2002	85	4.43	1,365	15,035
2003/04	89	4.51	1,389	21,139
2004/05	97	4.88	1,504	16,258
2005/06	98	5.08	1,565	15,974
2006/07	100	5.18	1,596	15,569
2007/08	102	4.80	1,478	18,613
2008/09	98	4.44	1,368	12,242
2009/10	114	3.80	1,170	15,928
2010/11	104	4.01	1,237	16,480
2011/12	91	4.33	1,336	17,551
2012/13	92	4.66	1,438	7,128

TAC's from 1987 to 1990, inclusive are for the fishing season May 1 to April 30, making 1986 a16 month year (January 1 1986-April 30, 1987).Effort calculated as catch/ CPUE.During 2003, there was an industry requested change in fishing season from Januar 1-December 31 to April 1 March 31,thus there was a season roll over making the 2003 Mar 2004 a 15 month year with a roll-over quota increase of 20,229 t.

Table 5. Small vessel (<500 t; length overall (loa) <100') Northern Shrimp fishery CPUE model for SFA 6, 1998-2012-13 (single trawl, year, size-class, month and area model using logbook data).

Year	Fleet Catch (T)	Percent Catch Captured In Model	CPUE Relative to 1998	Standardized Modelled CPUE	Effort (HRS)
1997	6,064	-	-	-	-
1998	30,073	80.24	1.00	288	104,450
1999	33,615	82.79	1.00	287	117,048
2000	43,203	87.08	1.16	333	129,677
2001	32,685	89.92	1.16	333	98,026
2002	39,863	92.86	1.03	297	134,222
2003/04	41,856	93.12	1.04	301	139,212
2004/05	53,316	91.92	1.50	433	123,191
2005/06	49,732	89.93	1.59	457	108,917
2006/07	50,817	92.13	1.59	459	110,789
2007/08	53,218	93.54	1.66	479	111,173
2008/09	57,764	94.23	1.49	428	134,970
2009/10	26,894	93.85	1.18	341	78,902
2010/11	41,122	89.11	1.33	384	107,146
2011/12	36,239	92.08	1.42	409	88,654
2012/13	40,802	67.39	1.43	412	99,071

TAC's for the small vessel fishery began in 1997 in all areas.

The Northern Shrimp catches are from CAQR reports

Effort calculated (Catch/CPUE) from small vessel (<500 t; LOA<100') logbook data

Table 6. SFA 6 stratified analysis of commercial large vessel catch data from the observer dataset (single and double trawl, all strata, January-May, by management year), 1989-2012-13. (Green 0-10,000 t; White 10,000-20,000 t; Pink > 20,000 t; Black = not fished).

Jan May Large vessel Shrimp Biomass 000 tonnes		Year																							
		1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Max depth (m)	STRATUM					18.1	24.8				20.6	47.5	65.3			26.9			1.43		36.9	55.7			
200	206																								
300	209							11.7	15.6	15.1	16.7	12.7		13.7	15.1	8.57		6.32	4.98				4.45		
	210		4.34	5.05	8.67	10		4.19					13.8		3.24	15.3	14.7	9.66	9.77	16.4	10.4	11.9	14.3	14.3	12.3
	213				0.53	27	28.7	15.4		25.7	19.3	32.2	38.6	33.5	48.3	39.2	31.6	22.4	47.3	22.3	45.1	45	13.1	3.07	
	214					9.79		21.3	36.4		22.4		32.8	18.4		23.8		25.8	18.7	26.7	23.4	42.6	2.45	18.4	
	215																					51	56.9		
	228	15	15.5	22.4	38.2	40.1	47.6	35.8	24.6	27.4	59.2	51.1	64.8	60.8	63.1	63.1	81.3	81.4	83.6	69.9	75.3	78.2	76.8	88	77.8
	620																	21	82.6						
	621		0.39																						
	624	11.1	6.54	6.65	11.3	12	24.3						26.4			29	29.6	19.6			19.8			8.52	
	634		2.25	0.81		9.62	13.7										43.1	42.9	40.8	29.6	38.5	6.22	52.2	31.5	49.4
	636																					11	4.84		
400	208	0.89	1.9	1.07	1.41	3.33	2.11	1.89	2.23	1.93	2.24	2.31	2.7	2.28	2.73	1.99									
	211				0.44	0.34	0.47	0.39	0.48	0.41	0.52	0.58	0.65	0.6	0.7	0.63	0.72	0.81	0.83	0.75	0.52	0.64	0.86	1.07	0.79
	216					0.27		2.71		2.79	2.18	2.29	3.17	1.27	1.78	3.33	3.41	1.92	2.32	2.53	3.59	3.8	3.79	4.41	1.98
	222			4.05	6.62	5.78	6.02	8.05	10.2	7.34	7.1	8.81	11	10.2	10.9	12.3	10.2	15.6	16.4	10.7	16.1	15	10.3	12.7	0.86
	229			0.58	9.9				9.24		14.6	13.3	16.6	14.5	14.2	19.8	25.6	20.6	22.7	20.1		27.3	23.1	30.5	16.9
	617	7.08	5.56	7.28	9.58	16.2	3.77	4.62	1.67	3.78	3.47	10.1	15.8	14.3	10.7	16.7	17.9	17.6	18.8	18.8	17.6	18.7	17.7	27.2	22.4
	623	0.08															16.3	13.7	16.5	12.4			2.99		
	625	1.99	0.71	5.62		12.4										0.51	26.1	21.4			24.9		23.6	23	38.4
	626		3.82													11.9									
	628																20.4	8.51							
	629		1.32														6.33								
	630	0.21	1.23														7.54	9.47	11.9	9.57	8.61				10.5
	633	8.84	10.8	20.3	27.4	27.8	43.5	28.7	39.1	44.3	18.2	22.7	36.9	35.2	33.2	69.3	65	61.5	69.7	74.8	55.3	59.7	58.9	71.2	59.1
	638		0.27			1.61							15.4			28.4	1.44	1.58	13.1	22.4		13.2			
	639		0.26			19.6		18.5			9.84		2.63	12	4.3	42.5	10.2	27.4	34.1			7.17			

Table 6 (Cont'd.)

Jan May Large vessel Shrimp Biomass 000 tonnes		Year																							
Max depth (m)	STRATUM	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
500	217							1.1	0.72		0.97	1.14	1.34	1.51	1.72	1.62	2.04	1		1.04	1.85	1.91	2.1	2.51	
	223				2.63	1.53	2.29	3.42	3.56	2.92	4.09	3.08	4.26	4.35	4.14	5.73	6.16	5.42	3.52	4.58	7.55	5.5	6.45	2.11	
	227			0.04	9.93	5.69	12.4	11.5	12.3	11.4	12.3	14.4	14.9	13.5	15.5	19.7	19.7	22.1	18.6	16.5	21	13.6	15	22	13.9
	235		0.61	0.13	0.89	1.64	1.1	0.85	1.18	0.84	0.99	0.95	1.06	1.43	1.32	1.3									
	240					1.21	2.8	2.57	3.03	2.24	1.4	2.37	2.63	2.27	3.16	4.34	7.98	3.97	4.44		0.03				
	622		6.63	9.49	10.9			3.4						13			24.5	25.4	22.8	19.6	27.9		1.33	30.6	
	627		1.03											4.03		2.99									
	631	6.26	7.06	10.7	18	21.4	14.9	14.9	4.53	23.7				20.7	40.3	40.4	36.3	33.6	40.8	44.1	22.9	44.1	27.4	46.1	40.3
	640					0.88						0.3													
	645	0				3.18	4.49	3.6	4.38						4.81	4.49									
750	212				4.66		4.9	3.35	7.41		4.95	3.61			6.31			7.53							
	218								1.4			1.54			1.48	2.62						2.45			
	224				2.61	2.91			5	3.58	4.41	4.66	7	6.01	6.31	7.84	6.54			3.4	5.25	8.47	10.2		
	230				4.22	1.79	3.64	3.24	3.69	3.11	4.66	5.19	4.56	4.27	4.32	5.33	5.64					5.47			
	641					3.21																			
	646						4.88																		
1000	231					1.16	7.64							3.84		6.54									
	236					1.98									8.7										
All		51.5	70.3	94.2	168	261	256	201	187	176	230	241	382	292	306	516	520	528	586	426	463	529	429	437	345

Table 7 SFA 6 percent contribution of large vessel commercial biomass by depth range, within all strata

Depth range (m)	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
201-300	0.00	0.00	0.00	0.00	0.07	0.10	0.00	0.00	0.00	0.09	0.20	0.17	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.08	0.11	0.00	0.00	0.00
301-400	0.51	0.41	0.37	0.35	0.42	0.45	0.44	0.41	0.39	0.51	0.40	0.46	0.43	0.42	0.35	0.38	0.43	0.49	0.39	0.46	0.47	0.53	0.37	0.40
401-500	0.37	0.37	0.41	0.33	0.34	0.23	0.32	0.34	0.34	0.25	0.25	0.27	0.31	0.26	0.40	0.41	0.38	0.35	0.40	0.27	0.28	0.33	0.39	0.44
501-750	0.12	0.22	0.22	0.25	0.14	0.15	0.21	0.16	0.23	0.09	0.09	0.06	0.21	0.23	0.16	0.19	0.17	0.15	0.20	0.18	0.12	0.12	0.24	0.16
751-1000	0.00	0.00	0.00	0.07	0.03	0.05	0.03	0.09	0.04	0.06	0.06	0.03	0.04	0.06	0.03	0.02	0.01	0.00	0.01	0.01	0.03	0.02	0.00	0.00
>1000	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 8. SFA 6 stratified analysis of index strata commercial large vessel catch data from the observer dataset (single and double trawl, January-May, by management year), 1992-2012-13. (Green 0-10,000 t; White 10,000-20,000 t; Pink > 20,000 t; Black = not fished).

Management year Index strata Large vessel Shrimp Biomass 000 tonnes		Year																				
		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Max depth (m)	STRATUM																					
300	228	38.2	40.1	47.6	35.8	24.6	27.4	59.2	51.1	64.8	60.8	63.1	62	81.3	80.4	83.8	69.5	75.3	73.6	76.8	88	77.8
400	211	0.44	0.34	0.47	0.39	0.48	0.41	0.52	0.58	0.65	0.6	0.7	0.63	0.72	0.81	0.83	0.75	0.52	0.6	0.86	1.07	0.79
	222	6.62	5.78	6.02	8.05	10.2	7.34	7.1	8.81	11	10.2	10.9	12.2	10.2	15.6	16.4	10.7	16.1	14.7	10.3	12.7	0.86
	617	9.58	16.2	5.77	4.14	1.67	3.78	3.47	10	15.4	13.9	10.7	13.6	17.8	17.5	18.2	17.8	17.2	17	16.7	27.2	19.3
	633	27.4	27.8	43.5	28.7	39.1	44.3	18.2	22.7	36.9	35.2	33.2	68.3	64.9	61.4	69.7	73.5	55.3	59.7	58.9	67.4	59.1
500	227	9.93	5.69	12.4	11.5	12.3	11.4	12.3	14.4	14.9	13.5	15.5	19.6	19.7	22.1	18.6	16.5	21	11.1	15	22	13.9
All		92.2	95.9	116	88.6	88.4	94.6	101	108	144	134	134	176	195	198	208	189	185	177	179	218	172

Table 9. SFA 6 percent contribution of large vessel commercial biomass, by depth range, within index strata.

Depth Range (m)	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
201-300	0.41	0.42	0.41	0.40	0.28	0.29	0.59	0.48	0.45	0.45	0.47	0.35	0.42	0.41	0.40	0.37	0.41	0.42	0.43	0.40	0.45
301-400	0.48	0.52	0.48	0.47	0.58	0.59	0.29	0.39	0.45	0.45	0.41	0.54	0.48	0.48	0.51	0.54	0.48	0.52	0.49	0.50	0.47
401-500	0.11	0.06	0.11	0.13	0.14	0.12	0.12	0.13	0.10	0.10	0.12	0.11	0.10	0.11	0.09	0.09	0.11	0.06	0.08	0.10	0.08
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 10. SFA 6 stratified analysis of commercial small vessel catch from the logbook dataset (single trawl, all strata, April-August), 1998-2012-13. (Green 0-10,000 t; White 10,000-20,000 t; Pink >20,000 t; Black not fished).

April to August Small vessel Shrimp Biomass 000 tonnes		Year														
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Max depth (m)	STRATUM															
200	205															
	206	13	11	9	14	8	12	12			15	17	14	15	20	23
	207	12					5									
	618			13	15		5					9	18		17	20
	619	6													15	
300	209	3	4	6	4	3							4	7	8	7
	210	3	3	3	3	3			7	5	5			6	6	
	213	17	12	14	15	14	10	16	20	20	19	22	18	21	24	8
	214	9	10	8	10		5	3			9	13	9	10	12	3
	228	29	18	20	24	19	17	16	24	31	24	29	13		28	26
	620	22	13	18	21	15	26	17	25	25	22	24	19	19	15	27
	621			19	29	17	14			28	23	27	22	19	18	23
	624	7	9	8	14	8	10	15	12	14	13	12	4	12	11	12
	634	9	8	12	15		10	23	15	16	23	19	14	17	12	10
	635		6	7	8	7	8				12	12	13	7	11	7
	636		13	16	13	10	18	18	20	20	17	19	6	12	11	4
	637		11	9	8		12	14	12	13	16	13	10	8	8	9
400	208	1	1	1	1	1							1	1	2	1
	211	0	0	0	0	0	0	0	0	0	0		0	0		
	216	1		2	2		1							1		
	222	4	3	4	5	4	3	4	6	7		5	4		5	10
	229	4	20	4	5	5			5							
	617	6	4	5	33	3	5	3	6	7	5	6	5	4	5	7
	623	2	2	4	6	3	3	3	5	5	4	4	3	3	4	5
	625	2	5	7	7	7	8	8	10	10	10	8	6	7	10	8
	626	3	6	6	7	6	6	9	8	9	8	7	7	7	6	7
	628	6	5	7		8	6	7	7	8	10	10	10	6	8	9
	629	1	1	1	3	2	1	2	1	3	2	2		2	2	2
	630	2		3		2	2	4	3	3	3	5	3	3	3	3
	633	17	22	19	16	13	16	28	25	25	39	26	17	19	21	21
	638	10	16	20	16	16	24	26	28	29	31	26	20	15	11	15
	639	9	14	15	13	12	14	19	22	20	20	14	14	13	14	10
500	217	1			1											
	223	3	1	1	1	1	2	1		2						
	227	4	4	5	5	5	4	3								
	235	0	0	0	1	0	0		1				0			0
	240		1	2	1	1	1			2						
	622	4	5	7	5	5	5	4	10	7	5	6	6		7	8
	627	1	2	2	2	2	2	2	2	2	4	11	2	2	2	2
	631	9		9	8	10	12	20	14	15	22	16	23	11	12	14
	640		1				1	2	1						1	0
	645			1									2			
	650			1	2		1	1		2	1	1				

Table 10 (Cont'd.)

April to August Small vessel Shrimp Biomass 000 tonnes		Year														
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
750	212	3	2	2	2	1		2			2	2				4
	218						1									1
	224	2	1	5	2	3	2	1								
	230		1		1	2										
	641			1	2	1	2	2	2		2		2	3	3	1
	646		4					5				6				
	651	2	3	4		4	6	4	5	5	6	4		3		
1000	231		1													
	236	1	1		1	3		1								
	642												4	3	4	4
	652			2		4		3			5		3			4
All		233	245	311	335	227	295	309	296	335	380	389	297	259	347	319

Table 11. SFA 6 percent contribution of small vessel commercial biomass, by depth range, within all strata.

Depthc range (m)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<= 200	0.16	0.04	0.10	0.09	0.04	0.13	0.06	0.00	0.00	0.04	0.10	0.11	0.08	0.20	0.15
201-300	0.42	0.44	0.45	0.48	0.42	0.44	0.41	0.46	0.51	0.48	0.49	0.44	0.52	0.46	0.43
301-400	0.29	0.40	0.32	0.34	0.36	0.30	0.37	0.43	0.38	0.35	0.29	0.30	0.31	0.26	0.31
401-500	0.09	0.06	0.09	0.08	0.11	0.09	0.11	0.09	0.09	0.08	0.09	0.11	0.05	0.06	0.08
501-750	0.03	0.04	0.04	0.02	0.05	0.04	0.05	0.02	0.01	0.03	0.03	0.01	0.02	0.01	0.02
751-1000	0.00	0.01	0.01	0.00	0.03	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.01	0.01	0.03
Total	1.00	1.00	1.00	1.01	1.00	1.00	1.00	1.00	0.99	0.99	1.00	0.99	1.00	1.01	1.00

Table 12. SFA 6 stratified analysis of index strata commercial small vessel catch data from the logbook dataset (single trawl, May-Aug.), 1998-2012. (Green 0-10,000 t; White 10,000-20,000 t; Pink > 20,000 t; Black = not fished).

Small vessel Shrimp Biomass 000 tonnes		Year														
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Max depth (m)	STRATUM															
300	213	17	12	14	15	14	10	16	20	20	19	22	18	21	24	8
	620	22	13	18	21	15	26	17	25	25	22	24	19	19	15	27
	624	7	5	8	14	8	10	15	12	14	13	12	4	12	11	12
400	617	6	4	5	33	3	5	3	6	7	5	6	5	4	5	7
	623	2	2	4	5	3	3	3	5	5	4	4	3	3	4	5
	625	2	5	7	7	7	8	8	10	10	10	8	6	7	10	8
	626	3	6	6	7	6	6	9	8	9	8	7	7	7	6	7
	633	17	22	19	16	13	16	28	25	25	39	26	17	19	21	21
	638	10	16	20	16	16	24	26	28	29	31	26	20	15	11	15
	639	9	14	15	13	12	14	19	22	20	20	14	14	13	14	10
500	627	1	2	2	2	2	2	2	2	2	4	11	2	2	2	2
All		96	105	119	148	99	124	145	163	168	175	159	115	123	123	122

Table 13. SFA 6 percent contribution of small vessel commercial biomass, by depth range, within index strata.

Depth Range (m)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
201-300	0.48	0.32	0.34	0.34	0.37	0.37	0.33	0.35	0.35	0.31	0.36	0.36	0.42	0.41	0.39
301-400	0.51	0.66	0.64	0.66	0.61	0.61	0.66	0.64	0.63	0.67	0.57	0.63	0.55	0.58	0.60
401-500	0.01	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.07	0.02	0.02	0.02	0.02
Total	1.00	1.00	0.99	1.01	1.00	1.00	1.01	1.00	0.99	1.00	1.01	1.00	0.99	1.00	1.00

Table 14. Hawke Channel + 3K (SFA 6) Northern shrimp biomass and abundance indices calculated from 1996 to 2012 Canadian autumn multi-species bottom trawl research survey data (standard tows = 15 min; at 3.0 Nmi/hr) using Ogive Mapping methods.

	Biomass (tons)			Abundance (numbers x 10^6)			Survey
Year	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	Sets
1996	406,848	500,279	596,630	96,381	115,669	139,744	238
1997	365,871	429,098	466,954	83,071	95,923	104,304	232
1998	404,834	461,618	512,461	93,904	105,828	118,098	234
1999	456,483	522,529	583,038	110,849	124,898	140,549	233
2000	504,306	576,594	638,714	122,628	137,610	151,020	241
2001	562,398	653,917	751,476	140,751	160,166	181,526	252
2002	536,524	605,993	658,347	132,596	146,898	159,276	253
2003	514,173	600,456	665,696	130,481	147,558	161,994	236
2004	593,005	656,736	744,025	129,575	144,117	163,605	214
2005	582,534	672,945	755,905	129,172	145,400	162,498	242
2006	774,934	894,743	1,023,916	181,828	208,164	238,008	234
2007	648,077	757,516	850,545	150,517	173,267	194,816	206
2008	546,491	634,989	719,057	127,562	146,174	161,088	173
2009	312,611	404,029	528,369	79,074	102,273	130,884	218
2010	307,779	360,132	410,070	72,137	82,787	93,491	235
2011	420,842	482,962	550,820	99,623	114,697	128,971	191
2012	311,504	395,370	499,675	74,684	92,916	116,990	223

Area compared each year = 157,479 sq. km

Table 15. SFA 6 (Hawke Channel + 3K) Northern Shrimp fishable biomass, exploitation rate and female spawning stock biomass (SSB) indices from autumn Canadian research bottom trawl survey data, 1996-2012.

			Fishable biomass tonnes			Catch/ previous year fishable biomass			Spawning Stock biomass tonnes		
Catch Year	Catch (t)	Survey Year	Lower 95%	Index	Upper 95%	Lower 95%	Index	Upper 95%	Lower 95%	Index	Upper 95%
1997	21,018	1996	240,625	315,128	378,960	5.55	6.67	8.73	149,006	200,957	243,545
1998	46,337	1997	257,237	309,692	345,232	13.42	14.96	18.01	145,583	183,439	211,227
1999	51,202	1998	313,014	359,025	398,290	12.86	14.26	16.36	184,446	214,046	240,222
2000	63,224	1999	355,904	411,681	465,343	13.59	15.36	17.76	223,006	260,459	297,610
2001	52,590	2000	359,226	416,513	472,391	11.13	12.63	14.64	247,673	299,020	338,788
2002	60,384	2001	441,381	520,616	618,276	9.77	11.60	13.68	290,764	353,085	424,870
2003/04	71,227	2002	425,574	491,016	540,048	13.19	14.51	16.74	298,315	349,058	385,302
2004/05	77,776	2003	362,347	432,622	483,264	16.09	17.98	21.46	263,580	323,183	366,475
2005/06	74,728	2004	399,599	454,671	523,133	14.28	16.44	18.70	325,498	378,859	436,851
2006/07	75,673	2005	421,547	505,112	570,252	13.27	14.98	17.95	325,599	395,471	450,946
2007/08	80,725	2006	555,250	669,824	791,445	10.20	12.05	14.54	389,128	462,927	541,457
2008/09	74,505	2007	476,720	566,224	638,613	11.67	13.16	15.63	353,286	430,105	493,231
2009/10	45,527	2008	434,031	509,944	585,555	7.78	8.93	10.49	285,327	339,996	407,653
2010/11	61,501	2009	232,168	310,698	422,957	14.54	19.79	26.49	159,477	204,984	276,165
2011/12	59,685	2010	247,371	295,395	343,117	17.39	20.21	24.13	154,342	190,185	222,704
2012/13*	60,245	2011	348,554	408,660	472,290	12.76	14.74	17.28	202,266	241,733	283,918
2013/14**	60,245	2012	245,458	316,236	408,660	14.74	19.05	24.54	144,979	187,164	228,846

Table 16. Modal analysis using Mix 3.01 (MacDonald and Pitcher 1993) of Pandalus borealis in Hawke Channel + 3K (SFA 6), from bottom autumn multi-species bottom trawl survey data.

Mean carapace length (Standard error)						
	Shrimp ages					
Year	1	2	3	4	5	6
1996	9.68 (.021)	14.92 (.012)	17.53 (.018)	20.37 (.029)	23.08 (.020)	25.93 (.039)
1997	9.68 (.032)	14.26 (.015)	17.52 (.023)	19.73 (.025)	23.15 (.018)	25.97 (.055)
1998	10.11 (.014)	14.09 (.031)	16.76 (.023)	19.55 (.018)	22.10 (.027)	24.59 (.032)
1999	10.25 (.013)	15.01 (.088)	18.44 (.028)	20.79 (.037)	22.91 (.030)	25.65 (.050)
2000	10.06 (.015)	14.17 (.011)	17.51 (.014)	20.36 (.032)	22.64 (.021)	25.04 (.060)
2001	10.09 (.038)	13.78 (.023)	16.52 (.037)	19.31 (.025)	22.49 (.032)	24.43 (.076)
2002	10.09 (.002)	14.44 (.037)	16.99(.051)	19.14 (.111)	21.60 (.039)	23.98 (.036)
2003	10.38 (.019)	14.41 (.021)	17.57 (.070)	19.55 (.092)	21.96 (.042)	24.34 (.049)
2004	10.72 (.031)	14.73 (.024)	17.14 (.042)	19.57 (.046)	22.10 (.024)	24.65 (.037)
2005	10.44 (.010)	14.60 (.200)	17.53 (.019)	19.89 (.033)	22.41 (.015)	24.91 (.035)
2006	10.43 (.015)	14.43 (.014)	17.73 (.091)	19.64 (.017)	22.63 (.031)	24.67 (.062)
2007	10.59 (.032)	13.83 (.024)	16.76 (.026)	20.07 (.040)	22.76 (.049)	24.61 (.089)
2008	10.29 (.055)	13.89 (.073)	16.51 (.103)	18.92 (.077)	22.36 (.039)	24.55 (.106)
2009	10.41 (.105)	13.06 (.054)	16.01 (.063)	18.56 (.047)	22.29 (.035)	24.63 (.068)
2010	10.37 (.061)	13.95 (.059)	16.69 (.044)	19.65 (.064)	22.26 (.053)	24.81 (.079)
2011	10.88 (.027)	14.70 (.027)	17.23 (.122)	19.34 (.081)	22.36 (.036)	24.94 (.072)
2012	10.83 (.030)	14.26 (.023)	17.44 (.05)	19.78 (.045)	22.55 (.033)	25.00 (.095)
2001	10.09 (.038)	13.78 (.023)	16.52 (.037)	19.31 (.025)	22.49 (.032)	24.43 (.076)

Estimated proportion (Standard error) contributed by each year class							
	Male ages				Female ages		
Year	1	2	3	4	5	6	Total
1996	.030 (.001)	.305 (.025)	.307 (.022)	.160 (.002)	.171 (.002)	.026 (.001)	.999
1997	.019 (.001)	.178 (.002)	.326 (.004)	.274 (.004)	.183 (.002)	.019 (.001)	.999
1998	.085 (.001)	.079 (.009)	.217 (.022)	.368 (.003)	.196 (.002)	.055 (.002)	1.000
1999	.074 (.001)	.287 (.002)	.195 (.003)	.242 (.003)	.182 (.004)	.020 (.001)	1.000
2000	.060 (.001)	.193 (.001)	.288 (.002)	.186 (.003)	.253 (.003)	.020 (.010)	1.000
2001	.021 (.001)	.182 (.002)	.206 (.003)	.295 (.003)	.257 (.003)	.038 (.004)	.999
2002	.047 (.001)	.126 (.003)	.293 (.004)	.157 (.007)	.289 (.005)	.088 (.003)	1.000
2003	.061 (.001)	.202 (.002)	.209 (.010)	.217 (.008)	.260 (.005)	.051 (.003)	1.000
2004	.021 (.001)	.198 (.003)	.230 (.003)	.220 (.003)	.283 (.003)	.048 (.001)	1.000
2005	.102 (.001)	.097 (.001)	.260 (.003)	.191 (.002)	.312 (.002)	.038 (.001)	1.000
2006	.069 (.001)	.261 (.002)	.122 (.008)	.260 (.007)	.250 (.025)	.038 (.003)	1.000
2007	.039 (.001)	.185 (.002)	.254 (.002)	.227 (.003)	.252 (.038)	.043 (.006)	1.000
2008	.028 (.001)	.130 (.006)	.224 (.008)	.269 (.009)	.314 (.005)	.035 (.005)	1.000
2009	.020 (.002)	.161 (.003)	.245 (.005)	.295 (.006)	.235 (.003)	.044 (.003)	1.000
2010	.022 (.001)	.107 (.004)	.310 (.004)	.265 (.005)	.255 (.005)	.041 (.003)	1.000
2011	.075 (.001)	.142 (.006)	.204 (.011)	.282 (.011)	.264 (.004)	.033 (.007)	1.000
2012	.049 (.001)	.204 (.002)	.222 (.005)	.277 (.005)	.230 (.003)	.019 (.002)	1.001

Table 16 (Cont'd.)

Distributional sigmas (Standard error) and constraints						
Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
1996	Sigmas Equal 1.0968 (0.005)					
1997	Sigmas Equal 1.1369 (0.007)					
1998	Sigmas Equal 1.0980 (0.006)					
1999	Sigmas Equal 1.0975 (0.004)					
2000	Sigmas Equal 1.0998 (0.005)					
2001	Sigmas Equal 1.2638 (0.010)					
2002	Sigmas Equal 1.2250 (0.010)					
2003	Sigmas Equal 1.2320 (0.009)					
2004	Sigmas Equal 1.1744 (0.009)					
2005	Sigmas Equal 1.0868 (0.005)					
2006	Sigmas Equal 1.2511 (0.007)					
2007	Sigmas Equal 1.3056 (0.011)					
2008	Sigmas Equal 1.4371 (0.020)					
2009	Sigmas Equal 1.3644 (0.017)					
2010	Sigmas Equal 1.3299 (0.018)					
2011	Sigmas Equal 1.3237 (0.014)					
2012	Sigmas Equal 1.2179 (0.011)					

Population at age estimates (10^6)							
Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Total
1996	.030 (.001)	.305 (.025)	.307 (.022)	.160 (.002)	.171 (.002)	.026 (.001)	.999
1997	.019 (.001)	.178 (.002)	.326 (.004)	.274 (.004)	.183 (.002)	.019 (.001)	.999
1998	.085 (.001)	.079 (.009)	.217 (.022)	.368 (.003)	.196 (.002)	.055 (.002)	1.000
1999	.074 (.001)	.287 (.002)	.195 (.003)	.242 (.003)	.182 (.004)	.020 (.001)	1.000
2000	.060 (.001)	.193 (.001)	.288 (.002)	.186 (.003)	.253 (.003)	.020 (.010)	1.000
2001	.021 (.001)	.182 (.002)	.206 (.003)	.295 (.003)	.257 (.003)	.038 (.004)	.999
2002	.047 (.001)	.126 (.003)	.293 (.004)	.157 (.007)	.289 (.005)	.088 (.003)	1.000
2003	.061 (.001)	.202 (.002)	.209 (.010)	.217 (.008)	.260 (.005)	.051 (.003)	1.000
2004	.021 (.001)	.198 (.003)	.230 (.003)	.220 (.003)	.283 (.003)	.048 (.001)	1.000
2005	.102 (.001)	.097 (.001)	.260 (.003)	.191 (.002)	.312 (.002)	.038 (.001)	1.000
2006	.069 (.001)	.261 (.002)	.122 (.008)	.260 (.007)	.250 (.025)	.038 (.003)	1.000
2007	.039 (.001)	.185 (.002)	.254 (.002)	.227 (.003)	.252 (.038)	.043 (.006)	1.000
2008	.028 (.001)	.130 (.006)	.224 (.008)	.269 (.009)	.314 (.005)	.035 (.005)	1.000
2009	.020 (.002)	.161 (.003)	.245 (.005)	.295 (.006)	.235 (.003)	.044 (.003)	1.000
2010	.022 (.001)	.107 (.004)	.310 (.004)	.265 (.005)	.255 (.005)	.041 (.003)	1.000
2011	.075 (.001)	.142 (.006)	.204 (.011)	.282 (.011)	.264 (.004)	.033 (.007)	1.000
2012	.049 (.001)	.204 (.002)	.222 (.005)	.277 (.005)	.230 (.003)	.019 (.002)	1.001

Table 17. SFA 6 Northern Shrimp recruitment indices defined as abundances of 11.5-17 mm carapace. If animals of both sexes and age 2 abundances from modal analysis.

Year	Lower 95% CL	11.5-17 mm recruitment index ($X10^6$)	Upper 95% CL	Age 2 modal analysis ($X10^6$)
1996	44,158	52,653	70,144	35,318
1997	29,016	33,345	36,919	17,072
1998	22,864	27,353	32,308	8,343
1999	35,178	41,279	50,280	35,792
2000	40,604	46,673	53,642	26,526
2001	50,441	57,949	66,308	29,101
2002	44,138	49,704	56,159	18,500
2003	41,349	47,447	55,505	26,558
2004	43,373	50,507	60,317	23,348
2005	30,355	35,347	41,239	14,116
2006	59,562	68,719	80,645	53,657
2007	55,948	64,882	73,829	32,013
2008	42,427	49,730	55,142	18,930
2009	33,184	42,999	53,240	16,342
2010	25,251	28,713	32,620	8,717
2011	29,791	34,804	40,081	16,337
2012	25,573	31,411	38,007	18,944

Table 18. Survival, annual mortality and instantaneous mortality rate indices for Northern Shrimp (Pandalus borealis) within Hawke Channel + 3K (SFA 6). Indices were calculated by combining 4 years of data in order to account for vagaries within the survey data and ageing by modal analysis. The survival, S, in the blue box is the sum of the age 5+ shrimp shaded green divided by the sum of the age 4+ shrimp shaded yellow. Median survival, annual mortality and instantaneous mortality rates were 0.59, 0.41 and 0.52 respectively.

Year	Age 4+ male and total female abundance (millions; yr=t)	Age 5+ male and female abundance (millions; yr=t)	Survival rate ($S = n_{t+1}/n_t$)	Annual mortality rate (A=1-S)	Instantaneous mortality Rate (Z=-ln(S))
1996	41,294	22,761	-	-	-
1997	45,608	19,425	-	-	-
1998	65,496	26,570	-	-	-
1999	55,419	25,259	0.52	0.48	0.65
2000	63,135	37,563	0.60	0.40	0.52
2001	94,590	47,299	0.59	0.41	0.52
2002	78,447	55,363	0.66	0.34	0.41
2003	84,636	53,074	0.66	0.34	0.42
2004	85,982	54,550	0.62	0.38	0.47
2005	78,720	50,894	0.66	0.34	0.41
2006	112,514	59,106	0.60	0.40	0.52
2007	90,515	51,111	0.58	0.42	0.55
2008	90,408	51,100	0.51	0.49	0.67
2009	58,445	28,423	0.44	0.56	0.82
2010	45,634	24,127	0.48	0.52	0.73
2011	66,412	34,123	0.42	0.58	0.87
2012	48,833	23,123			

Table 19. Survival, annual mortality and instantaneous mortality rate indices for Northern shrimp (Pandalus borealis) within Hawke Channel + 3K (SFA 6). Indices were calculated by combining 4 years of data in order to account for vagaries within the observer dataset and were normalized by the number of sets within each year. Survival, S, in the blue box is the sum of the multiparous females (shaded green) divided by the total of all females in the sample from the previous year (shaded yellow). Median survival, annual mortality, and instantaneous mortality rates were 0.60, 0.40 and 0.50 respectively. This analysis is based upon the Observer dataset. The data were limited to June-July to ensure that there were very few ovigerous females as it would be impossible to detect whether these were primiparous or multiparous animals.

Year	Total count ovigerous females per set	Total count females per set	Total count multiparous females females per set	Survival rate (S = nt+1/nt)	Annual mortality rate (A=1-S)	Instantaneous mortality rate (Z=-ln(S))
1998	-	326	40	-	-	-
1999	-	218	120	-	-	-
2000	-	202	97	-	-	-
2001	-	249	194	0.78	0.22	0.25
2002	-	255	157	0.62	0.38	0.48
2003	-	225	130	0.58	0.42	0.55
2004	1	130	102	0.79	0.21	0.24
2005	-	226	103	0.46	0.54	0.78
2006	-	220	123	0.56	0.44	0.58
2007	1	194	99	0.51	0.49	0.67
2008	-	200	157	0.79	0.21	0.24
2009	1	172	104	0.60	0.40	0.50
2010	-	139	61	0.44	0.56	0.82
2011	-	104	63	0.61	0.39	0.50
2012	-	158	80	-	-	-

Table 20. Original multiplicative specification for large vessel Northern Shrimp catch per unit effort (CPUE) model for SFA 5, 1980-2012-13. (single + double trawl, observer data, no windows, history >3 years, standardized to 2012-13 values).

Year	Tac (T)	Fleet Catch (T)	Percent catch in Model	CPUE Relative to 2012	Standardized modelled CPUE	Effort (HRS)
1977	-	2,686	-	-	-	-
1978	5,300	3,630	-	-	-	-
1979	4,000	3,727	-	-	-	-
1980	4,800	4,108	17	0.45	1,027	3,999
1981	4,800	3,449	13	0.49	1,130	3,051
1982	4,800	1,983	14	0.43	991	2,001
1983	4,800	1,000	-	-	-	-
1984	4,200	1,002	14	0.37	847	1,183
1985	3,570	1,689	13	0.29	672	2,514
1986	4,400	4,826	-	-	-	-
1987	4,800	5,956	-	-	-	-
1988	4,800	7,838	-	-	-	-
1989	6,000	5,985	6	0.58	1,322	4,526
1990	6,000	5,360	11	0.52	1,182	4,534
1991	6,375	6,118	16	0.41	928	6,596
1992	6,375	6,315	15	0.36	812	7,778
1993	6,375	5,719	42	0.38	877	6,518
1994	7,650	7,499	83	0.45	1,036	7,236
1995	7,650	7,616	97	0.62	1,412	5,393
1996	7,650	7,383	90	0.78	1,789	4,126
1997	9,180	15,103	86	0.83	1,891	7,985
1998	9,180	14,827	80	0.87	1,994	7,437
1999	9,180	14,945	91	0.89	2,030	7,360
2000	9,180	14,368	99	0.98	2,235	6,429
2001	9,180	15,001	99	1.04	2,383	6,294
2002	9,180	15,128	88	1.02	2,325	6,507
2003/04	26,564	29,882	54	0.99	2,260	13,222
2004/05	16,780	20,778	117	0.91	2,078	9,997
2005/06	16,780	21,762	84	0.92	2,099	10,367
2006/07	16,780	22,501	104	0.96	2,188	10,285
2007/08	16,780	23,747	112	0.97	2,210	10,747
2008/09	16,780	20,409	77	0.86	1,969	10,366
2009/10	16,780	25,094	89	0.90	2,056	12,203
2010/11	16,780	21,045	112	0.96	2,184	9,638
2011/12	16,780	23,985	95	0.91	2,074	11,566
2012/13	16,780	16,684	114	1.00	2,286	7,299

During 2003, a 2,500 t scientific quota was created for the large vessels in SFA5 and there was an industry requested change in fishing season from Januar 1-December 31 to April 1-March 31, thus there was a season rollover making the 2003 - March 2004 a 15 month year with rollover increase in quota of 9,787 t.

Table 21. Proposed multiplicative specification for large vessel Northern Shrimp catch per unit effort (CPUE) model for SFA 5, 1980-2012-13. (single + double trawl, observer data, no windows, history > 3 years, standardized to 2012-13 values).

Year	TAC (t)	Percent catch in model	CPUE Relative to 1980	Standardized Modelled CPUE	Effort (HRS)
1977	-	-	-	-	-
1978	5,300	-	-	-	-
1979	4,000	-	-	-	-
1980	4,800	17	1.00	1,031	3,985
1981	4,800	13	1.09	1,126	3,062
1982	4,800	14	0.96	993	1,997
1983	4,800	-	-	-	-
1984	4,200	14	0.83	851	1,178
1985	3,570	13	0.66	676	2,498
1986	4,400	-	-	-	-
1987	4,800	-	-	-	-
1988	4,800	-	-	-	-
1989	6,000	6	1.26	1,297	4,614
1990	6,000	11	1.15	1,186	4,519
1991	6,375	16	0.90	928	6,593
1992	6,375	15	0.80	820	7,697
1993	6,375	42	0.85	879	6,505
1994	7,650	83	1.01	1,039	7,218
1995	7,650	97	1.36	1,403	5,427
1996	7,650	90	1.72	1,772	4,166
1997	9,180	86	1.84	1,900	7,949
1998	9,180	80	1.92	1,977	7,498
1999	9,180	91	1.96	2,022	7,393
2000	9,180	99	2.16	2,225	6,458
2001	9,180	99	2.30	2,370	6,329
2002	9,180	88	2.24	2,308	6,555
2003/04	26,564	91	2.04	2,106	14,186
2004/05	16,780	92	2.11	2,179	9,537
2005/06	16,780	92	2.17	2,234	9,739
2006/07	16,780	96	2.04	2,107	10,677
2007/08	16,780	101	1.99	2,048	11,594
2008/09	16,780	101	2.00	2,059	9,911
2009/10	16,780	99	2.05	2,114	11,873
2010/11	16,780	107	1.96	2,023	10,403
2011/12	16,780	91	2.11	2,177	11,017
2012/13	16,780	63	2.51	2,585	6,455

During 2003, a 2,500 t scientific quota was created for the large vessels in SFA5 and there was an industry requested change in fishing season from January 1-December 31 to April 1-March 31, thus there was a season rollover making the 2003 - Mar. 2004 a 15 month year with rollover increase in quota of 9,787 t.

Table 22. SFA 5 stratified analysis of commercial large vessel catch data from the observer dataset (single and double trawl, all strata, Jan-May, by management year), 1988-2012-13. (Green 0-10,000 t; White 10,000-20,000 t; Pink > 20,000 t; Black = not fished).

Management year all strata Large vessel Shrimp Biomass 000 tonnes		Year																								
		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Max depth (m)	STRATUM																									
200	201																	11.8	16.1				17.2		7.98	
	205																						11.9			
	238			6.25																						
	954		11.4	9.2	8.02	8.98	15.6	10.9	7.3	20.3	14	26.1	19.6	14.9	34.2	19.4	20.4	25	44.1	45		22.9	36.9	45.6	27.1	36.1
	956				7.24		3.51							11.5				26.9						20.9		
300	202			0.61																						
	214					0.2		8.77	7.1	8.59	6.6	9.14	7.09	6.05	10.6	8.36	14.7	19.7	13.3	8.15	12.8	11.3	11.8	11.6	18	15.4
	215		15.3	13.7	8.47	22.7	11.6	11.2	12.7	5.24	20.2	21.5	26.4	30	31.3	34.3	33.6	36.9	33.6	36.7	34.7	41.4	41.2	41.1	40.1	42.5
	943			2.38	1.89	3.36		3.75						0.56					14							
	950				2.15																		12.8			
	953	4.71	2.01	3	2.62	2.93	2.54	3.21	4.24	0.72	4.27	5.77	4.26	5.3	4.91	4.62	5.64	5.91	7.92	8.37	5.53	7.93	8.67	9.61	7.08	7.34
	955	1.81			4.64	5.7	5.53	5.2	5.48	5.78	6.79	7.43	8.89	8.07	8.2	11.3	10.6	12.2	12.5	12.3	12.5	10.6	17.5	14.4	15.2	16.1
	958																						22	12.5	12.8	16
400	203	6.34	4.93	7	5.46	7.51	6.51	5.19	7.81	9.56	8.36	10.4	9.81	11.9	11.6	13.3	11.7	14.3	14.4	15.2	18.8	17.6	18.9	15.3	18.8	16.4
	216						0.36	3.3	4.02	4.1	3.89	4.4	3.68	4.59	5.05	6.32	6.81	6.95	6.23	5.75	6.51	7	8.13	7.99	9.26	7.23
	932					1.35		0.14	0.8	1.29	0.53	0.97	1.12	0.64	1.02	0.83	1.53	0.82	1.56	1.77		1.22	1.68			
	944	5.37	8.21	7.58	8.74	8.33	11.9	9.77	10.6	9.04	4.48	14.5	13.8	20.4	22.5	20.1	25	27.8	26	25.5	28.1	27.1	30.5	31.4	32.5	31.9
	949				0.89	0.39														8.21						
	952	2.75	1.27	1.89	1.57	1.94	2.11	2.6	3.11	2.7	3.09	3.67	3.01	4.13	3.88	4.31	4.67	4.01	6.33	5.87	6.15	5.25	6.44	7.97	5.77	5.82
	959										0											4.9	6.68	5.76	5.61	

Table 22 (Cont'd.)

Management year all strata Large vessel Shrimp Biomass 000 tonnes		Year																								
Max depth (m)	STRATUM	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
500																		11.8	16.1				17.2		7.98	
	201																	11.8	16.1				17.2		7.98	
	204		2.24	3.45	2.23	1.63	5.26	2.97	3.83	5.32	4.37	5.86	7.39	7.81	6.74	8.3	7.51	4.62	7.05	6.97	10.3	11	14.1	7.75	10.8	
	217				0.01		0.11	3.02	3.44	4.13	2.65	4.3	4.18	4.39	4.61	5.45	6.46	5.91	5.5	6.3	5.8	5.58	5.88	6.93	8.96	4.31
	933					0.77				0.16			1.25				1.24	0.67	1.12	1.31			1.56			
	942					0	1.03	0.62	0.81	1.63	0		0.47	1.22	1.27	1.19	1.19	1.64	1.8	2.07	1.94	1.92	2.15	2.22	2.47	
	945		7.9	4.12	5.35	5.15	7.56	6.48	11	4.14	2.11	7.95	1.21					8.17								
	948			1	1.37	0.93	1.14	2.18						3.16				2.27								
750	951	2.66	1.66	2.04	1.49	2.11	2.48	2.78	3.25	2.79	4.06	3.94	3.52	5.51	4.07	5.22	8.04	4.71	8.43	6.17			6.84	7.54		
	960		0			0														4.95	2.92				5.04	
	218							1.87	3.62	5.28	2.79	4.69	6.14	6.36	6.85	6.97	8.27	8.09	8.37	6.96	8.91	7.19	12.7	7.91	4.25	
	239		0.59	1.46	0.38		1.93	2.23	2.15	1.48	2.18	2.36			2.97	4.72	5.4	1.82	2.64	4.11		4.61	6.97	4.72	6.71	
	934					0.89					0.25								3.68							
	941							1.7	0.75	2.63	0.46		0.69	2.69	2.51	2.31	2.71	2.79	3.92	4.05	3.42	3.41	3.88	4.21	5.43	5.14
	946			0.07		4	15.4					25.9														
1000	947	0.71	1.55	1.34	1.08	1.71	1.8	2.84	1.83	3.68	3.1			5.16	4.17	6.94	7.76	6.21	5.9							
	961																	6.76		7.55	6.38			7.04	6.7	
	219								5.48		3.05		9.16		5.67	3.24	6.36	6.53	6.46							
	935					1.17																				
	940							0.57											2.38	1.31						
All		24.4	57.2	65.1	63.6	81.7	96.5	91.3	99.3	98.6	97.2	159	132	155	172	167	189	252	253	225	165	192	304	273	251	204

Table 23. SFA 5 percent contribution of large vessel commercial biomass by depth range, within all strata, January-May.

Depth range (m)	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<= 200	0.00	0.20	0.24	0.24	0.11	0.20	0.12	0.07	0.21	0.14	0.16	0.15	0.17	0.20	0.12	0.11	0.25	0.24	0.20	0.00	0.12	0.22	0.24	0.14	0.18
201–300	0.27	0.30	0.30	0.31	0.43	0.20	0.35	0.30	0.21	0.39	0.28	0.35	0.32	0.32	0.35	0.34	0.30	0.32	0.29	0.40	0.37	0.37	0.33	0.37	0.48
301–400	0.59	0.25	0.25	0.26	0.24	0.22	0.23	0.27	0.27	0.21	0.21	0.24	0.27	0.26	0.27	0.26	0.21	0.22	0.28	0.36	0.33	0.23	0.25	0.29	0.30
401–500	0.11	0.21	0.16	0.16	0.13	0.18	0.20	0.22	0.18	0.14	0.14	0.14	0.14	0.10	0.12	0.13	0.11	0.09	0.12	0.13	0.10	0.10	0.09	0.11	0.02
501–750	0.03	0.04	0.04	0.02	0.08	0.20	0.09	0.08	0.13	0.09	0.21	0.05	0.09	0.10	0.13	0.13	0.10	0.10	0.10	0.11	0.08	0.08	0.09	0.09	0.03
750-1000	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.06	0.00	0.03	0.00	0.07	0.00	0.03	0.02	0.03	0.03	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 24. SFA 5 stratified analysis of commercial large vessel catch data from the observer dataset (single + double trawl, index strata; January-May; after 2002 data were converted to management year), 1994-2012-13. (Green 0-10,000 t; White 10,000-20,000 t; Pink >20,000 t; Black not fished).

Management year Index strata Large vessel Shrimp Biomass 000 tonnes		Year																		
		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Max depth (m)	STRATUM	8.77	7.1	8.59	6.8	9.14	7.09	6.05	10.63	8.36	14.57	17	13.3	8.78	12.75	11.29	11.77	9.08	17.98	15.4
300	214																			
	215	11.23	12.7	5.24	20.15	21.5	26.39	30.01	31.27	34.33	33.86	36.6	33.59	36.73	34.65	41.41	41.19	40.07	40.1	42.5
	953	3.21	4.24	0.72	4.27	5.77	4.26	5.3	4.91	4.62	5.64	6.91	7.92	8.37	5.53	7.93	8.67	9.31	7.08	7.34
	955	5.2	5.48	5.78	6.79	7.43	8.89	8.07	8.2	11.28	10.5	12.1	11.52	12.28	12.54	10.58	17.54	14.4	15.22	16.1
400	203	5.19	7.81	9.56	8.36	10.4	9.81	11.92	11.63	13.34	11.66	13.9	14.35	15.18	18.75	17.64	18.85	15.33	18.79	16.4
	216	3.3	4.02	4.1	3.89	4.4	3.68	4.99	5.06	6.32	6.56	6.95	6.23	5.79	6.51	7	8.13	7.99	9.26	7.23
	944	9.77	10.6	9.04	4.48	14.5	13.8	20.39	22.47	20.09	24.5	26	24.39	25.47	28.14	27.08	30.49	31.25	32.45	31.9
	952	2.6	3.11	2.7	3.09	3.67	3.01	4.13	3.88	4.31	4.67	4.01	6.25	5.87	6.15	5.25	6.44	7.89	5.77	5.82
500	217	3.02	3.44	4.13	2.65	4.3	4.18	4.39	4.61	5.45	6.51	5.94	5.5	6.3	5.8	6.58	5.88	6.93	8.96	4.31
All		52.28	58.5	49.85	60.29	81.1	81.11	95.26	102.6	108.1	118.5	127	123	124.8	130.8	134.8	147	142.2	155.6	147

Table 25. SFA 5 percent contribution of large vessel commercial biomass by depth range, within index strata, January-May.

Depth Range (m)	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
201-300	0.54	0.50	0.41	0.63	0.54	0.57	0.52	0.54	0.54	0.54	0.56	0.54	0.53	0.50	0.53	0.54	0.51	0.52	0.55
301-400	0.40	0.44	0.51	0.33	0.41	0.37	0.43	0.42	0.41	0.40	0.39	0.42	0.42	0.46	0.42	0.42	0.44	0.43	0.42
401-500	0.06	0.06	0.08	0.04	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.04	0.05	0.04	0.05	0.04	0.05	0.06	0.03
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 26. Autumn Northern Shrimp (Pandalus borealis) biomass and abundance indices within Hopedale and Cartwright Channels (SFA 5), as determined using Ogive Mapping calculations.

Year	Biomass (tons) Lower C.I.	Biomass (tons) Estimate	Biomass (tons) Upper C.I.	Abundance (numbers x 10^6) Lower C.I.	Abundance (numbers x 10^6) Estimate	Abundance (numbers x 10^6) Upper C.I.	No. Sets
1996	63,146	152,228	330,834	13,672	39,225	94,317	111
1997	88,679	128,367	177,197	18,837	28,428	40,373	112
1998	62,240	85,981	121,118	12,706	17,350	24,878	120
1999	73,003	105,513	148,100	14,307	20,941	29,852	117
2000	-	-	-	-	-	-	-
2001	189,580	249,284	329,224	46,283	62,087	83,272	90
2002	-	-	-	-	-	-	-
2003	-	-	-	-	-	-	-
2004	129,575	186,459	239,115	27,778	40,249	53,381	120
2005	-	-	-	-	-	-	-
2006	155,249	188,372	236,799	34,735	41,868	50,803	118
2007	-	-	-	-	-	-	-
2008	102,694	158,873	233,376	24,415	34,792	48,558	96
2009	-	-	-	-	-	-	-
2010	99,160	178,808	268,111	24,999	43,253	63,610	94
2011	140,751	175,687	216,865	33,164	40,596	48,528	95
2012	133,904	176,391	216,865	31,664	43,801	55,394	96

Table 27. SFA 5 (Hopedale and Cartwright Channels) Northern Shrimp fishable biomass, exploitation rate and female spawning stock biomass (SSB) indices from autumn Canadian research bottom trawl survey data, 1996-2012.

			Fishable biomass tonnes			Catch/previous year Fishable biomass			Spawning Stock biomass		
Catch year	Catch (t)	Survey year	Lower 95%	Index	Upper 95%	Lower 95%	Index	Upper 95%	Lower 95%	Index	Upper 95%
1997	15,103	1996	46,403	86,283	145,080	10.41	17.50	32.55	21,868	33,224	47,753
1998	15,170	1997	70,164	101,787	137,428	11.04	14.90	21.62	28,553	39,668	50,290
1999	15,109	1998	50,511	70,677	100,781	14.99	21.38	29.91	26,851	37,956	50,239
2000	14,694	1999	62,935	90,813	128,669	11.42	16.18	23.35	33,506	50,139	69,016
2001	15,116	2000	-	-	-	-	-	-	-	-	-
2002	15,339	2001	137,428	183,540	246,867	6.21	8.36	11.16	67,174	96,451	129,273
2003/04	30,437	2002	-	-	-	-	-	-	-	-	-
2004/05	24,033	2003	-	-	-	-	-	-	-	-	-
2005/06	22,904	2004	102,492	150,617	200,555	11.42	15.21	22.35	61,928	86,484	110,547
2006/07	22,612	2005	-	-	-	-	-	-	-	-	-
2007/08	23,768	2006	125,548	155,349	196,024	12.13	15.30	18.93	60,851	81,651	106,721
2008/09	20,503	2007	-	-	-	-	-	-	-	-	-
2009/10	25,094	2008	73,063	128,367	198,440	12.65	19.55	34.35	45,457	82,155	126,051
2010/11	21,425	2009	-	-	-	-	-	-	-	-	-
2011/12	25,264	2010	76,003	144,979	226,832	11.14	17.43	33.24	35,701	64,637	99,925
2012/13*	23,300	2011	113,466	144,677	184,446	12.63	16.10	20.53	52,797	75,510	103,197
2013/14**	23,300	2012	110,547	147,194	182,533	12.76	15.83	21.08	46,373	63,026	79,004

* Catch up to January 28, 2013

** Assumes that the 2013/14 will remain at 23,300 t and will be taken

Table 28. SFA 5 Northern Shrimp recruitment indices defined as abundances of 11.5-17 mm carapace lf animals of both sexes.

Year	lower 95% CL	Recruitment index ($x10^6$)	Upper 95% CL
1996	3,961	20,415	59,170
1997	4,460	7,160	11,276
1998	2,481	3,339	4,536
1999	2,772	4,113	5,820
2000	-	-	-
2001	16,783	24,748	33,325
2002	-	-	-
2003	-	-	-
2004	6,305	9,545	13,531
2005	-	-	-
2006	9,115	11,448	14,105
2007	-	-	-
2008	9,421	11,925	15,585
2009	-	-	-
2010	8,330	13,711	18,928
2011	8,974	11,852	13,944
2012	8,253	12,972	16,824

Table 29. Survival, annual mortality and instantaneous mortality rate indices for Northern shrimp (Pandalus borealis) within Hopedale and Cartwright Channels (SFA 5). Indices were calculated by combining 4 years of data in order to account for vagaries within the observer dataset and were normalized by the number of sets within each year. Survival, S, in the blue box is the sum of the multiparous females (shaded green) divided by the total of all females in the sample from the previous year (shaded yellow). Median survival, annual mortality, and instantaneous mortality rates were 0.41, 0.59 and 0.90 respectively. This analysis is based upon the Observer dataset. The data were limited to June-July to ensure that there were very few ovigerous females as it would be impossible to detect whether these were primiparous or multiparous animals.

Year	Total count ovigerous females per set	Total count females per set	Total count multiparous females females per set	Survival rate (S = nt+1/nt)	Annual mortality rate (A=1-S)	Instantaneous mortality rate (Z=-ln(S))
1997	0	117	42	-	-	-
1998	0	100	47	-	-	-
1999	0	250	51	-	-	-
2000	0	81	52	0.64	0.36	0.44
2001	1	201	86	0.43	0.57	0.84
2002	0	236	56	0.24	0.76	1.43
2003	0	250	153	0.61	0.39	0.49
2004	0	178	51	0.29	0.71	1.24
2005	0	217	66	0.30	0.70	1.19
2006	0	233	79	0.34	0.66	1.08
2007	0	184	80	0.44	0.56	0.83
2008	0	177	112	0.63	0.37	0.46
2009	1	171	85	0.50	0.50	0.70
2010	5	126	33	0.26	0.74	1.33
2011	0	152	58	0.38	0.62	0.96
2012	1	180	124			

Table 30. Original multiplicative specification for large vessel Northern Shrimp catch per unit effort (CPUE) model for SFA 4, 1989-2012-13. (Single + double trawl, observer data, no windows, history > 3 years, standardized to 2012-13 values).

Year	TAC (t)	Fleet catch (t)	Percent catch in model	Standardized CPUE modelled Relative 1989	CPUE	Effort (HRS)
1978	500	-	-	-	-	-
1979	500	3	-	-	-	-
1980	500	<1	-	-	-	-
1981	500	2	-	-	-	-
1982	500	5	-	-	-	-
1983	500	30	-	-	-	-
1984	500		-	-	-	-
1985	500		-	-	-	-
1986	500	2	-	-	-	-
1987	500	7	-	-	-	-
1988	500	1,083	-	-	-	-
1989	2,580	3,842	9	1.00	1,165	3,297
1990	2,580	2,945	33	0.63	736	4,000
1991	2,635	2,561	43	3.13	3,649	702
1992	2,635	2,706	53	1.82	2,123	1,275
1993	2,735	2,723	67	2.89	3,371	808
1994	4,000	3,982	67	3.20	3,735	1,066
1995	5,200	5,104	62	1.21	1,411	3,617
1996	5,200	5,160	74	1.35	1,571	3,285
1997	5,200	5,216	53	2.66	3,104	1,680
1998	8,008	7,918	71	2.05	2,391	3,312
1999	8,008	7,793	73	2.11	2,463	3,165
2000	8,008	7,300	72	2.37	2,765	2,640
2001	8,008	8,104	65	3.73	4,346	1,864
2002	8,008	8,322	69	2.24	2,608	3,191
2003/04	12,685	12,944	53	2.53	2,949	4,389
2004/05	9,883	9,549	81	1.83	2,139	4,465
2005/06	9,883	10,247	73	1.79	2,086	4,912
2006/07	9,883	10,084	73	2.06	2,401	4,199
2007/08	9,883	10,009	78	2.34	2,727	3,670
2008/09	10,783	9,682	83	2.49	2,903	3,336
2009/10	10,783	10,656	67	3.47	4,049	2,632
2010/11	10,783	11,134	82	3.65	4,251	2,619
2011/12	10,783	10,441	58	3.06	3,568	2,926
2012/13	12,341	13,148	52	2.46	2,864	4,590

Effort calculated (Catch/CPUE) from large vessel observer data, single and double trawl, no windows. During 2003, a 1,125 t Scientific Quota was created for the large vessels in SFA 4 and there was an industry requested change in fishing season from January 1-December 31 to April 1 - March 31, thus there was a season roll-over making the 2003 - March 2004 season a 15 month year with a roll-over quota of 1,183 t in SFA 4 N and 1,618 t in SFA 4S. After 2010, it became no longer necessary to fish part of the quota in the south

*Table 31. **Proposed** multiplicative specification for large vessel Northern Shrimp catch per unit effort (CPUE) model for SFA 4, 1989-2012-13. (single + double trawl, observer data, no windows, history > 3 years, standardized to 2012-13 values). The data after 2002 were converted to management year and the model has been standardized to 1989*

Year	TAC (t)	Fleet catch (t)	Percent catch in model	Standardized CPUE modelled Relative 1989	CPUE	Effort (HRS)
1978	500	-	-	-	-	-
1979	500	3	-	-	-	-
1980	500	<1	-	-	-	-
1981	500	2	-	-	-	-
1982	500	5	-	-	-	-
1983	500	30	-	-	-	-
1984	500		-	-	-	-
1985	500		-	-	-	-
1986	500	2	-	-	-	-
1987	500	7	-	-	-	-
1988	500	1,083	-	-	-	-
1989	2,580	3,842	9		1,179	3,258
1990	2,580	2,945	33		736	4,002
1991	2,635	2,561	43		3,673	697
1992	2,635	2,706	53		2,143	1,263
1993	2,735	2,723	67	1.00	3,371	808
1994	4,000	3,982	67	1.11	3,733	1,067
1995	5,200	5,104	62	0.42	1,409	3,622
1996	5,200	5,160	74	0.47	1,571	3,285
1997	5,200	5,216	53	0.93	3,121	1,671
1998	8,008	7,918	71	0.71	2,392	3,310
1999	8,008	7,793	73	0.73	2,461	3,166
2000	8,008	7,300	72	0.82	2,754	2,650
2001	8,008	8,104	65	1.29	4,338	1,868
2002	8,008	8,322	69	0.77	2,599	3,202
2003/04	12,685	12,944	64	0.78	2,640	4,904
2004/05	9,883	9,549	70	0.67	2,273	4,200
2005/06	9,883	10,247	79	0.63	2,115	4,844
2006/07	9,883	10,084	74	0.70	2,348	4,295
2007/08	9,883	10,009	70	0.80	2,690	3,721
2008/09	10,783	9,682	85	0.86	2,899	3,340
2009/10	10,783	10,656	72	1.19	4,007	2,659
2010/11	10,783	11,134	74	1.25	4,222	2,637
2011/12	10,783	10,441	62	1.02	3,443	3,032
2012/13	12,341	12,536	51	0.85	2,878	4,356

Effort calculated (Catch/CPUE) from large vessel observer data, single and double trawl, no windows. During 2003, a 1,125 t Scientific Quota was created for the large vessels in SFA 4 and there was an industry requested change in fishing season from January 1-December 31 to April 1-March 31, thus there was a season roll-over making the 2003 - March 2004 season a 15 month year with a roll-over quota of 1,183 t in SFA 4 N and 1,618 t in SFA 4S. After 2010, it became no longer necessary to fish part of the quota in the south

Table 32. Stratified analysis of NAFO Subdivision 2G (SFA 4) large vessel catch data from the observer dataset (single + double trawl, all strata; June-December), 1989-2012-13. Green = 0-10,000 t; White = 10,000-20,000 t; Pink>20,000 t; Black not fished. After 2002, data were converted to management year.

Management year Large vessel Shrimp Biomass 000 tonnes		year																						
		1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Max depth (m)	STRATUM																		1.63	8.29	6.71		15.17	14.55	15.66
200	925																								
	930															48.6									
	931															2.61				7.39				9.91	8.5
300	901																20.25			30.79	26.24	48.77	40.92	54.61	49.32
	908	4.14	5.07			9.95			13.02	6.37	12.7	11.54	14.16	19.34	14.73	16.1	17.61	18.99	19.44	20.41	22	29.25	24.7	27.55	27.84
	911	3.48	5.28								13.3	15.11	16.6		10.22	15.51		20.88	4.68	12.87	20.34	26.83	24.66	28.26	
	924	5.19	1.56		11.4	13.25	11.8		10.82	14.6	14.9	20.68	21.82	20.39	20.45	23.05	24.39	22.03	24.72	24.71	27.46	32.16	38.38	31.07	32.83
	926										4.07		11.36		12.07			2.48	2.22	4.66	6.32	3.74	8.22	8.58	12.02
400	902	0.75	0.77	0.06	0.14	0.49			1.21	1.48	2.87	2.51	3.17	3.58	3.06	3.99	3.02	3.84	4.56	5.06	4.11	6.56	4.07	5.21	5.31
	912	0.62	0.1							0.43		1.55	0.27		1.11										
	923	3.33	1.28	6.92	3.8	3.45	3.48	3.28	2.83	4.34	4.26	4.65	5.54	6.24	5.8	6.71	5.59	5.26	7.03	7.17	7.2	9.26	10.12	4.87	5.03
	927			16.17	6.35	7.12	0.24	4.22	3.47	10.2	6.02	3.67	9.08		5.49	0.95	13.6	3.29	9.04	10.5	9.73	10.71	6.01	4.47	0.88
500	903	0.47								0.72		1.19	1.95	2.85	2.76	3.04	2.03	2.45	2.76	2.56	3.68	5.31	0.68	3.36	
	913	0.49										0.84													
	922	3.11	3.48	2.75	2.12	2.74	2.05	2.21	2.55	2.83	3.17	3.18	3.53	4.28	4.19	5.05	4.03	4.76	3.93				8.45		0
	928		5.51	6.48	5.6	5.63	2.34	3.97	4.73	0.12		4.99	4.58		0.32										
750	904	0.09												5.37	5.01	8.21	2.14	3.42	5.2		4.99				
	914	1.09																							
	921		1.07						1.41						1.9										
	929				0.01			4.81	3.95																
1000	905																	5.94	5.06						
All		22.76	24.1	32.37	29.4	42.62	19.9	18.5	43.98	41.1	61.3	69.89	92.06	62.05	87.11	133.8	92.65	93.34	91.17	134.4	137.8	172.6	181.4	192.5	157.4

Table 33. SFA 4 percent contribution of large vessel commercial biomass, by depth range within all strata.

Depth range (m)	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<=200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.38	-	-	0.02	0.12	0.05	-	0.08	0.13	0.15
201-300	0.56	0.49	-	0.39	0.54	0.59	-	0.54	0.51	0.73	0.68	0.69	0.64	0.66	0.41	0.67	0.69	0.56	0.70	0.74	0.82	0.75	0.78	0.78
301–400	0.21	0.09	0.72	0.35	0.26	0.19	0.41	0.17	0.40	0.21	0.18	0.20	0.16	0.18	0.09	0.24	0.13	0.23	0.17	0.15	0.15	0.11	0.08	0.07
401–500	0.18	0.37	0.29	0.26	0.20	0.22	0.33	0.17	0.09	0.05	0.15	0.11	0.11	0.08	0.06	0.07	0.08	0.07	0.02	0.03	0.03	0.05	0.02	-
501–750	0.05	0.04	-	0.00	-	-	0.26	0.12	-	-	-	-	0.09	0.08	0.06	0.02	0.04	0.06	-	0.04	-	-	-	-
751-1000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	0.07	-	-	-	-	-	-
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 34. NAFO Subdivision 2G (SFA 4) Northern Shrimp biomass and abundance indices determined from the NSRF-DFO joint shrimp bottom trawl survey data using Ogive Mapping calculations (Standard tow = 15 min. at 3.0 Nmi/hr; 2005-11 the MV. Cape Ballard was the research platform over the 2005-11 period, but was replace by the MV. Aqviq during 2012; in all cases the standard Campelen 1800 research trawl was used).

	Biomass (t)			Abundance (numbers x 10^6)			Survey
Year	Lower C.I.	Estimate	Upper C.I.	Lower C.I.	Estimate	Upper C.I.	Sets
2005	33,406	70,979	116,185	6,278	13,997	23,509	78
2006	53,723	107,426	160,484	9,609	20,335	32,016	76
2007	86,575	133,502	204,783	15,475	23,496	35,802	77
2008	92,293	148,100	247,572	19,049	29,609	49,263	69
2009	112,560	205,186	415,708	22,129	41,594	84,380	75
2010	81,188	146,288	284,421	17,257	30,850	62,250	72
2011	88,468	153,134	296,100	16,854	29,397	57,871	76
2012	139,845	214,146	330,130	29,791	45,398	70,416	78

Area compared each year 43,570 sq km

Table 35. SFA 4 Northern Shrimp biomass within index strata over the period 2005-2012. Data are from the summer NSRF-DFO joint shrimp survey. (Green <10,000 t; White 10,000-20,000 t; Pink > 20,000 t).

Survey Summer SFA 4 Shrimp 000 Biomass tonnes		Year							
		2005	2006	2007	2008	2009	2010	2011	2012
<=200	909	6	0	0	0	0	0	1	0
	910	0	0	0	1	0	0	0	0
	925	0	0	1	1	0	0	0	1
	930	[redacted]	0	1	2	0	0	0	1
201 - 300	901	13	8	46	47	58	12	21	47
	908	29	27	28	38	80	50	44	47
	911	18	3	7	8	4	23	14	32
	924	3	17	44	42	29	31	16	66
	926	3	23	2	1	7	0	1	2
	931	[redacted]	0	5	0	0	0	0	0
301 - 400	902	0	0	0	2	1	0	0	1
	912	0	0	0	0	0	0	0	0
	923	6	23	1	2	4	12	0	0
	927	0	0	0	4	0	2	0	1
401 - 500	903	0	0	0	0	0	0	0	0
	913	0	0	0	0	0	[redacted]	0	0
	922	0	0	0	[redacted]	0	0	0	0
	928	0	0	0	[redacted]	0	0	0	0
501 - 750	904	0	0	0	0	0	0	0	0
	914	0	0	0	[redacted]	0	0	[redacted]	
	921	0	0	0	0	0	0	0	0
	929	0	0	0	0	0	0	0	0
All		78	101	134	147	185	130	98	198

Table 36. SFA 4 percent contribution of research total biomass, by depth range.

Depth range (m)	2005	2006	2007	2008	2009	2010	2911	2012
<= 200	0.08	0.00	0.01	0.03	0.00	0.00	0.01	0.01
201-300	0.85	0.77	0.99	0.93	0.96	0.89	0.98	0.98
301-400	0.08	0.23	0.01	0.05	0.03	0.11	0.00	0.01
401-500	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
501-750	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	1.00	1.00	1.01	1.01	0.99	1.00	0.99	1.00

Table 37. SFA 4 (NAFO Subdivision 2G) Northern Shrimp fishable biomass, exploitation rate and female spawning stock biomass (SSB) indices from the NSRF-DFO joint shrimp research bottom trawl survey data, 2005-06-2012-13.

		Fishable biomass			Catch/ within year fishable			Female Spawning Stock		
Management Year	Catch (t)	Lower C.I.	Biomass(t) Index	Upper C.I.	Lower C.I.	Biomass Index	Upper C.I.	Lower C.I.	Biomass(t) Index	Upper C.I.
2005/06	10,247	29,399	62,321	102,694	10.0	16.4	34.9	17,186	34,533	52,807
2006/07	10,084	45,618	92,424	135,717	7.4	10.9	22.1	30,597	53,360	72,832
2007/08	10,009	72,560	113,970	176,593	5.7	8.8	13.8	54,297	80,846	121,219
2008/09	9,682	74,463	119,004	194,715	5.0	8.1	13.0	53,058	88,296	157,262
2009/10	10,656	94,307	179,512	370,603	2.9	5.9	11.3	66,831	130,985	272,339
2010/11	11,134	59,039	127,058	255,324	4.4	8.8	18.9	28,825	70,879	150,013
2011/12	10,441	71,956	129,777	248,176	4.2	8.0	14.5	57,478	87,491	147,798
2012/13	13,148	122,628	191,393	301,537	4.4	6.9	10.7	75,913	109,540	164,813

Table 38. SFA 4 Northern Shrimp recruitment indices defined as abundances of 11.5-17 mm carapace lf animals of both sexes.

	Recruitment index ($X10^6$)		
	Lower 95 %		Upper 95 %
Year	C.I.	Estimate	C.I.
2005	942	1,803	2,898
2006	1,426	3,609	6,917
2007	2,175	3,050	4,501
2008	5,057	7,729	12,021
2009	4,612	8,319	16,421
2010	3,281	5,618	9,853
2011	2,689	4,621	7,790
2012	3,995	6,064	9,408

Table 39. Survival, annual mortality and instantaneous mortality rate indices for Northern shrimp (Pandalus borealis) within NAFO Subdivision 2G (SFA 4). Indices were calculated by combining 4 years of data in order to account for vagaries within the observer dataset and were normalized by the number of sets within each year. Survival, S, in the blue box is the sum of the multiparous females (shaded green) divided by the total of all females in the sample from the previous year (shaded yellow). Median survival, annual mortality, and instantaneous mortality rates were 0.51, 0.49 and 0.67 respectively. This analysis is based upon the Observer dataset. The data were limited to June-July to ensure that there were very few ovigerous females as it would be impossible to detect whether these were primiparous or multiparous animals. Please note that this analysis did not include 2010 or 2011 data as there were relatively high numbers of ovigerous females.

Year	Total count ovigerous females per set	Total count females per set	Total count multiparous females females per set	Survival Rate (S =nt+1/nt)	Annual mortality rate (A=1-S)	Instantaneous mortality rate (Z=-ln(S))
1996	-	219	101	-	-	-
1997	-	201	89	-	-	-
1998	-	259	105	-	-	-
1999	-	251	210	0.60	0.40	0.51
2000	-	232	156	0.57	0.43	0.57
2001	-	234	62	0.51	0.49	0.67
2002	1	160	74	0.50	0.50	0.69
2003	-	220	150	0.50	0.50	0.69
2004	-	231	139	0.54	0.46	0.62
2005	6	231	91	0.56	0.44	0.58
2006	-	215	92	0.49	0.51	0.71
2007	5	183	119	0.50	0.50	0.68
2008	3	183	132	0.51	0.49	0.67
2009	1	167	74	-	-	-
2010	10	141	71	-	-	-
2011	11	147	92	-	-	-
2012	-	208	143	-	-	-

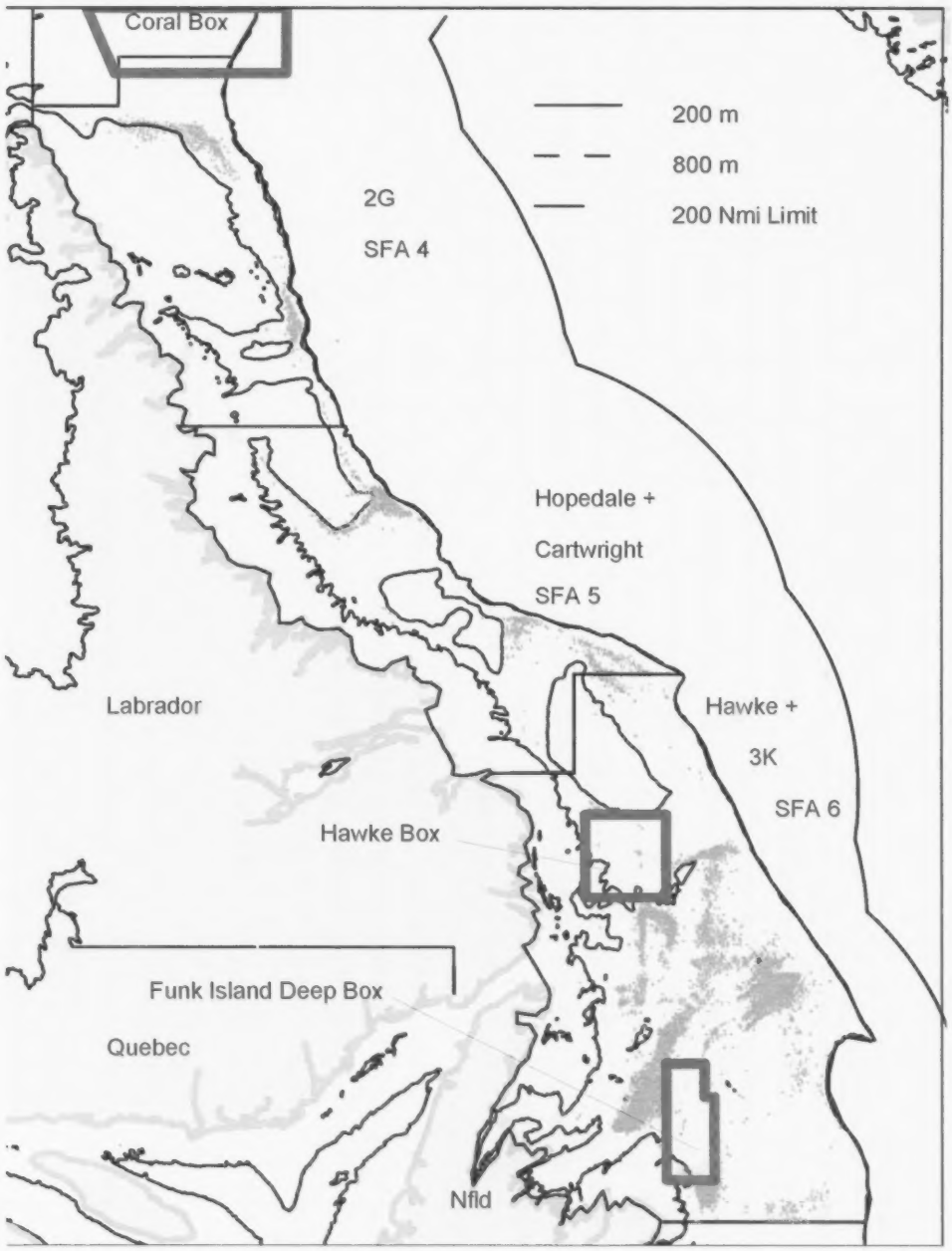


Figure 1. Map of Northern Shrimp Fishing Areas (SFAs) including the large voluntary coral box, Hawke Channel and Funk Island Deep closed areas. The red crosses indicate large and small vessel fishing positions during 2012-13.

Figure 2 Historical Northern Shrimp catches and TACs in SFAs 4-6 for the period 1977-2012-13 (2012-13 catch is up to January 28, 2013). In 2003, the management year changed to a fiscal year

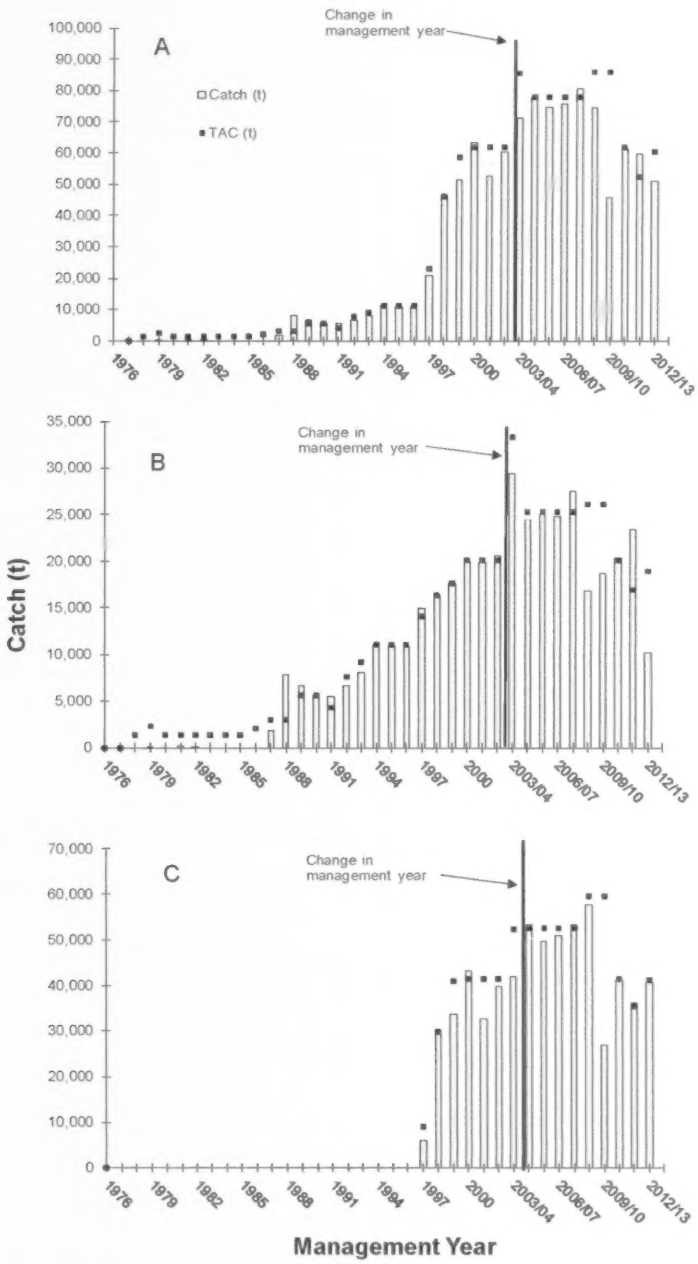


Figure 3. Historical Northern Shrimp catches (SFA 6) and TACs for the period 1976-2012-13 (2012-13 catches are up to January 28, 2013). In 2003, the management year changed to a fiscal year. A = total catch; B = large vessel catch; C = small vessel catch.

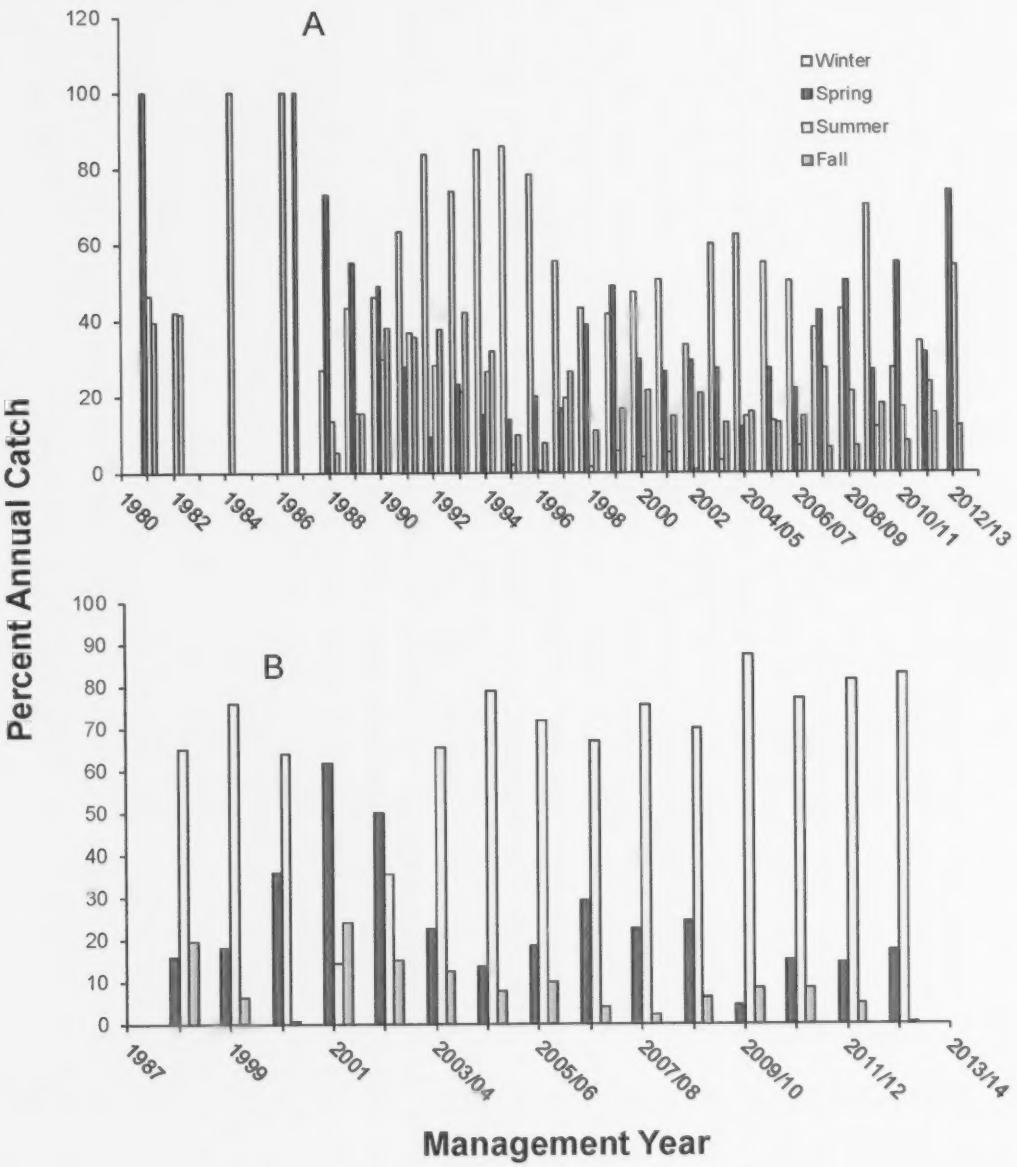


Figure 4 Seasonality of the large (A) and small (B) vessel fleets fishing shrimp in SFA 6

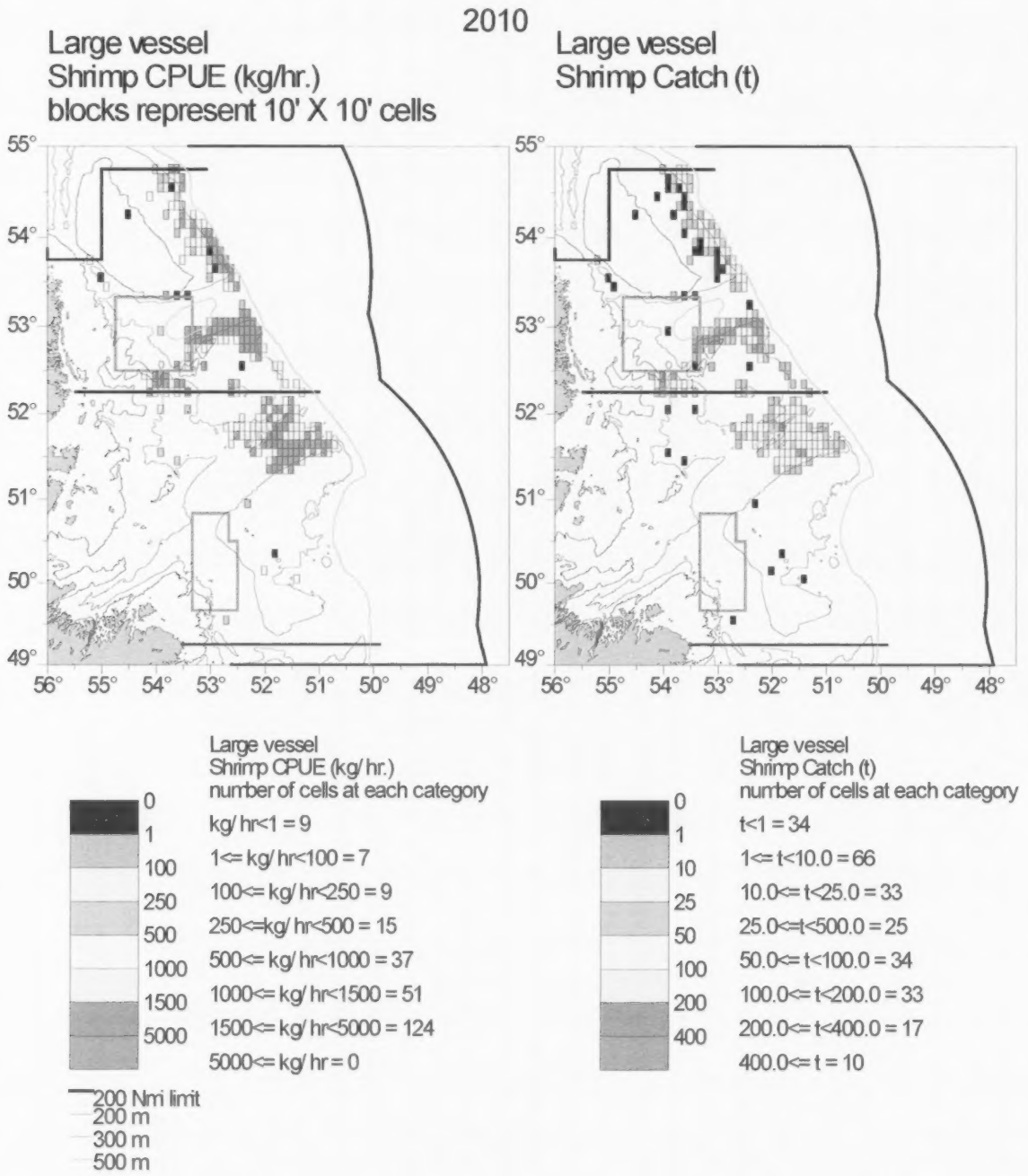


Figure 5 Large vessel (>500 t) catch and average fishery performance within the 2010-11 SFA 6 Northern Shrimp fishery

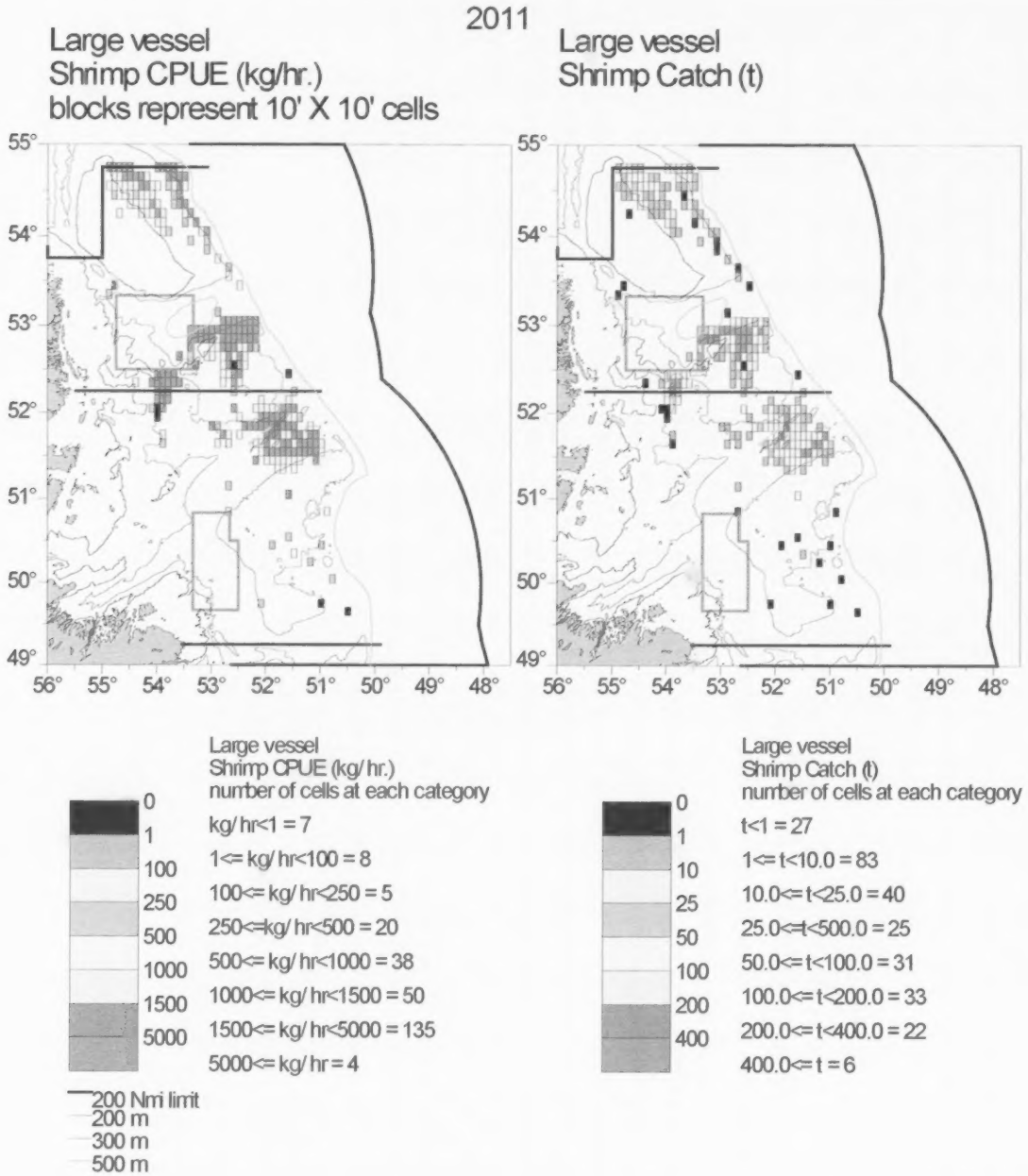


Figure 6 Large vessel (>500 t) catch and average fishery performance within the 2011-12 SFA 6 Northern Shrimp fishery

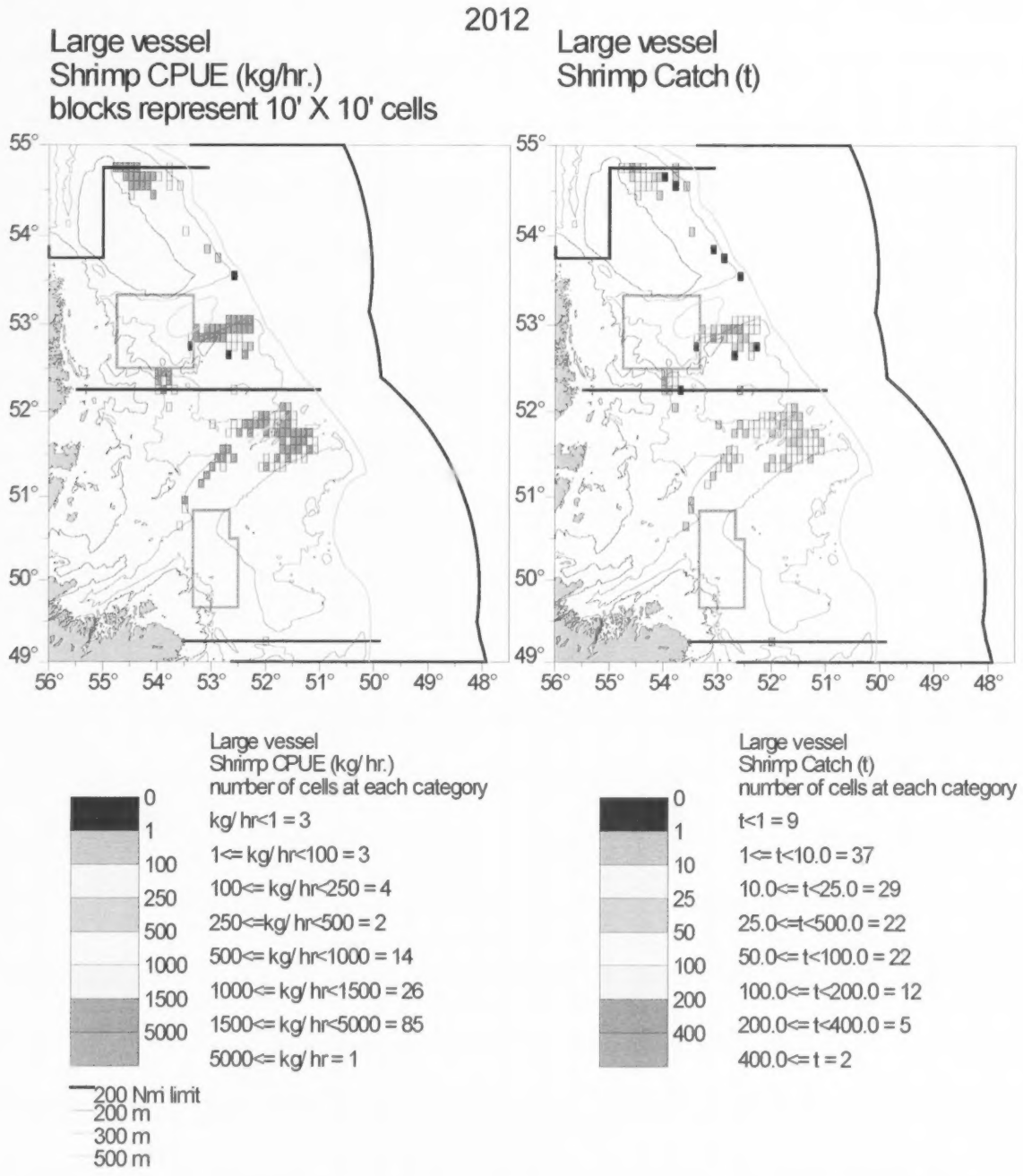


Figure 7 Large vessel (>500 t) catch and average fishery performance within the 2012-13 SFA 6 Northern Shrimp fishery. (Data were up to January 28, 2013)

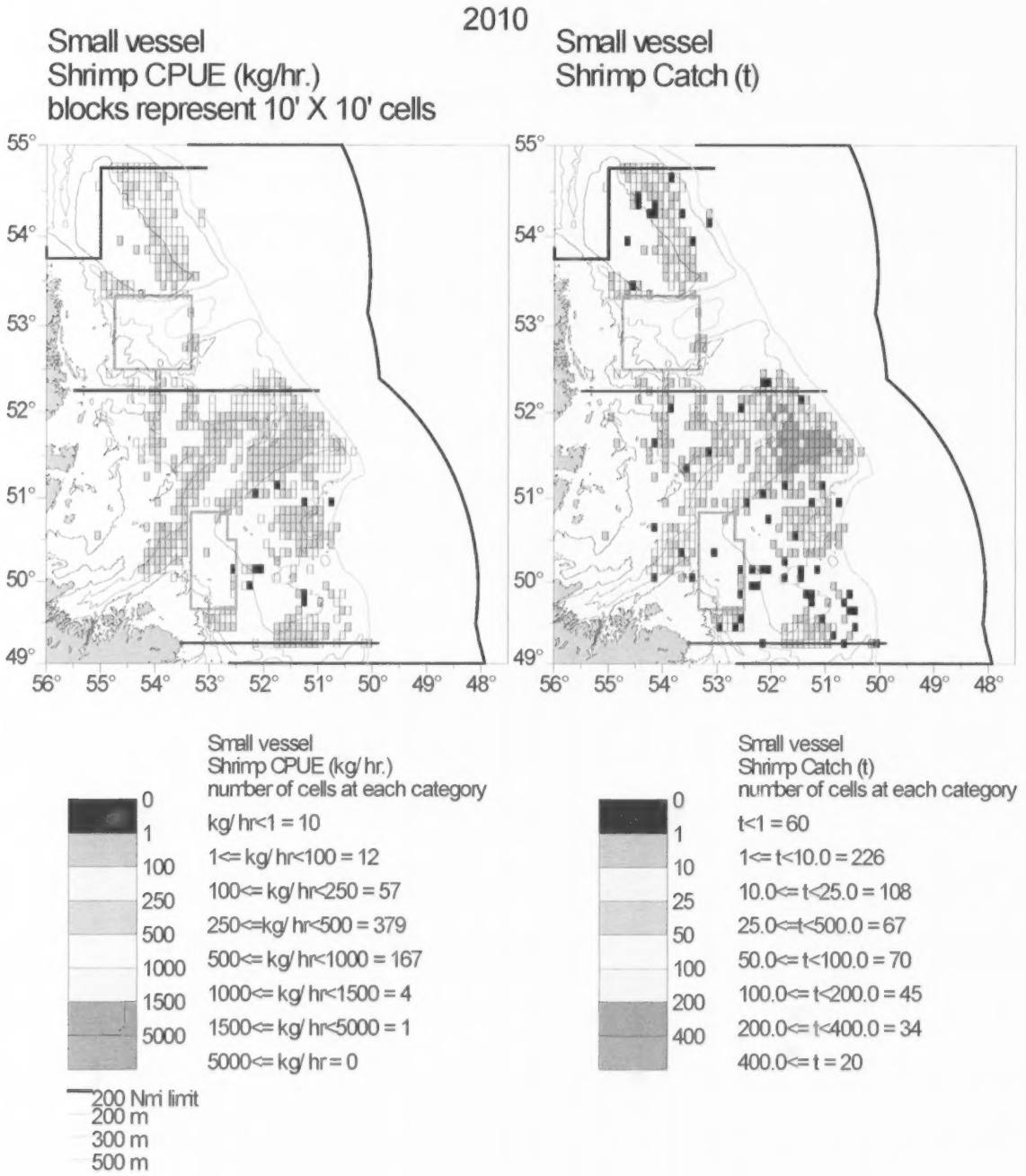


Figure 8 Small vessel (<=500 t; LOA<100') catch and average fishery performance within the 2010-11 SFA 6 Northern Shrimp fishery

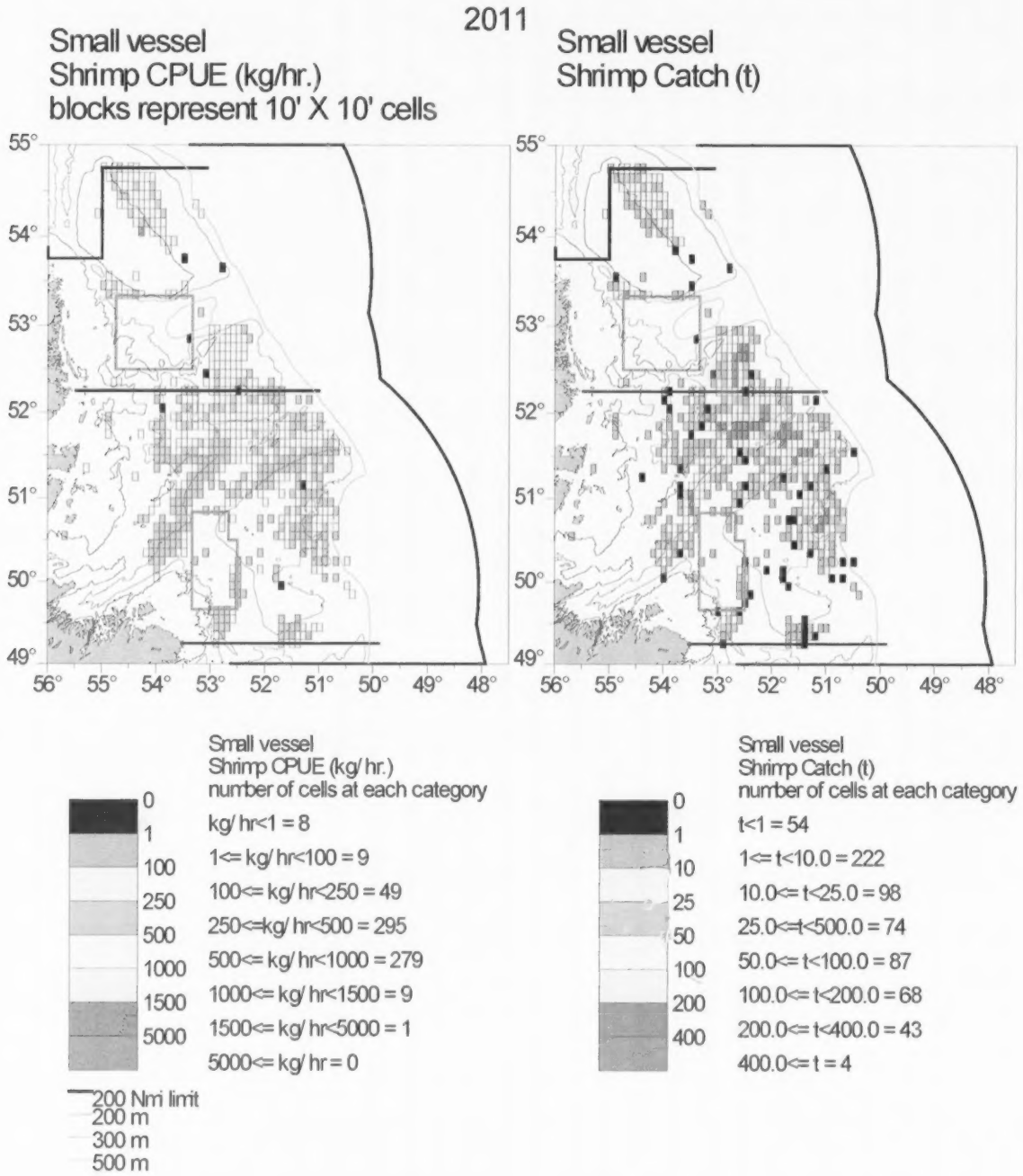


Figure 9 Small vessel (<=500 t; LOA<100') catch and average fishery performance within the 2011-12 SFA 6 Northern Shrimp fishery

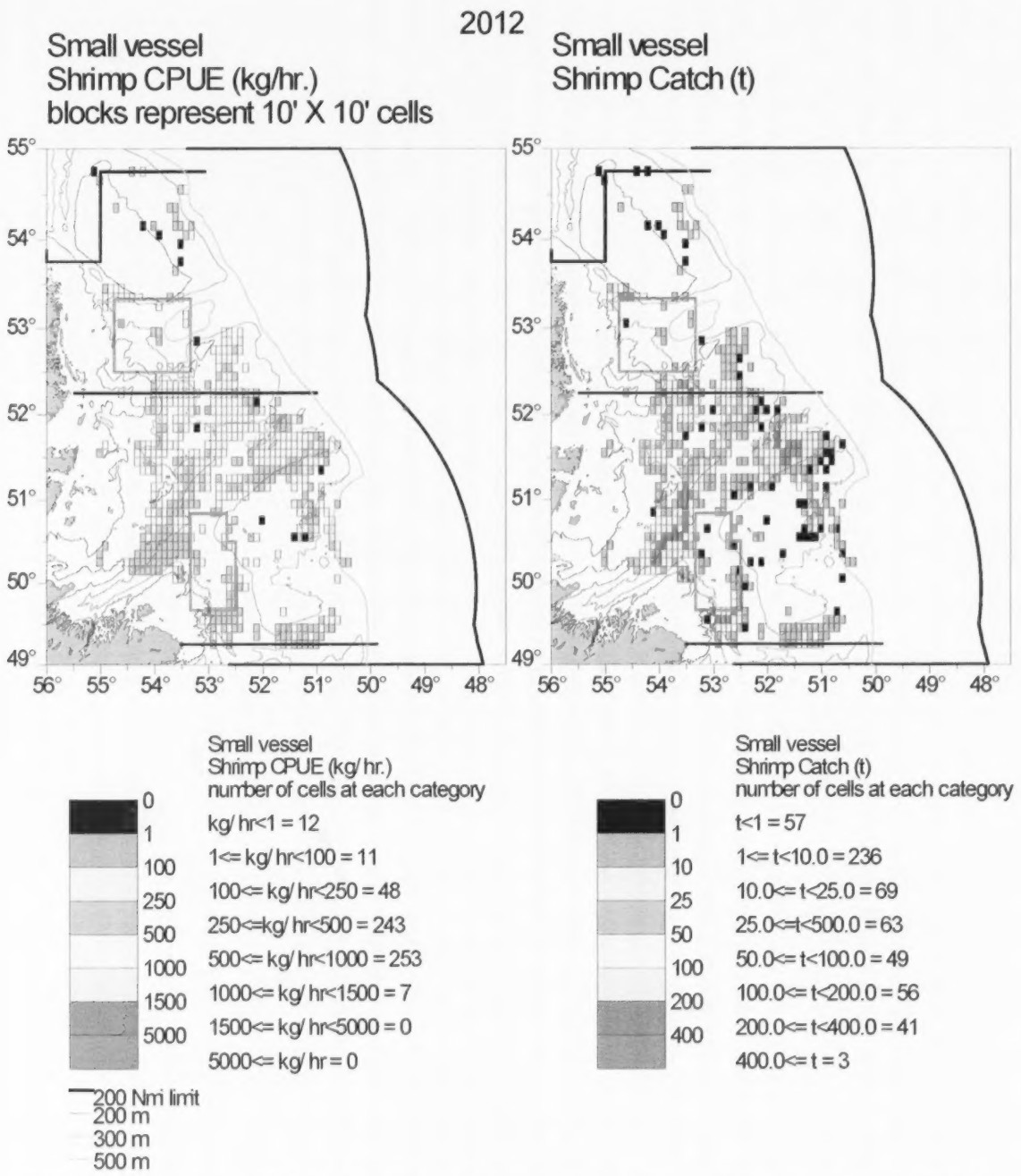


Figure 10 Small vessel (<=500 t; LOA<100') catch and average fishery performance within the 2012-13 SFA 6 Northern Shrimp fishery. (Data were up to January 28, 2013)

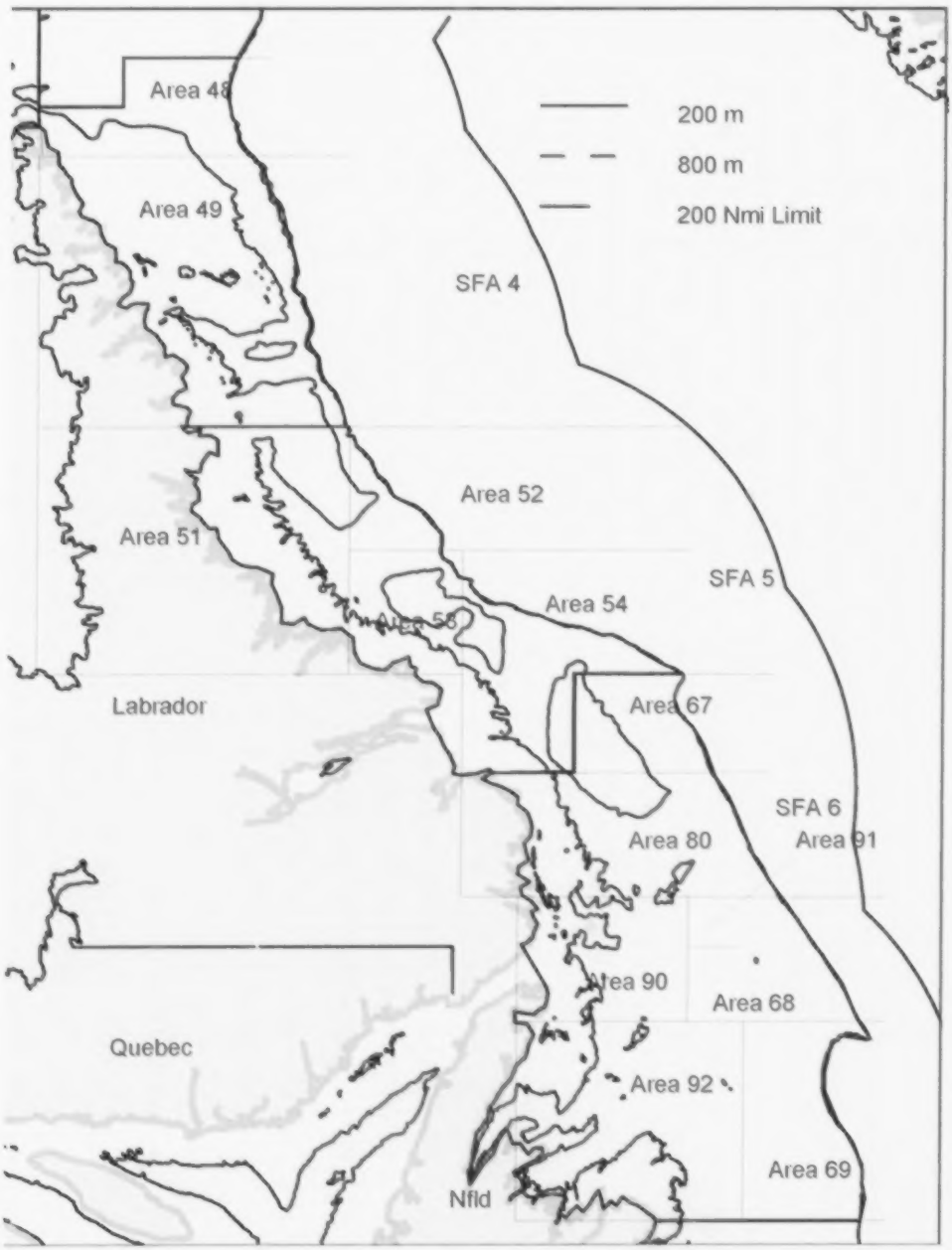


Figure 11 SFAs broken into areas used in commercial catch rate models

The GLM Procedure

Class Level Information

Class	Levels	Values
year	24	1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012
month	12	1 2 3 4 5 7 8 9 10 11 12 13 Standardized to March values
CFV	26	
gear	2	2 10 (Single trawl = 2; Double trawl = 10)
area	6	67 68 69 80 90 92

Number of Observations Read 2497
Number of Observations Used 2497

Dependent Variable: lncpue
Weight: effort

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	65	50095.94911	770.70691	96.16	<.0001
Error	2431	19483.79661	8.01473		
Corrected Total	2496	69579.74572			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.719979	38.38447	2.831029	7.375455

Source	DF	Type I SS	Mean Square	F Value	Pr > F
year	23	33868.17694	1472.52943	183.73	<.0001
month	11	6807.16478	618.83316	77.21	<.0001
CFV	25	7877.29606	315.09184	39.31	<.0001
gear	1	923.63191	923.63191	115.24	<.0001
area	5	619.67943	123.93589	15.46	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	23	14043.12564	610.57068	76.18	<.0001
month	11	5356.61066	486.96461	60.76	<.0001
CFV	25	5889.85659	235.59426	29.40	<.0001
gear	1	1012.19043	1012.19043	126.29	<.0001
starea	5	619.67943	123.93589	15.46	<.0001

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Intercept		6.523644797 B	0.27018727	24.14	<.0001
year	1989	-1.541403261 B	0.06747836	-22.84	<.0001
year	1990	-1.298536745 B	0.06230984	-20.84	<.0001
year	1991	-0.958482738 B	0.05672865	-16.90	<.0001
year	1992	-0.874643722 B	0.05810030	-15.05	<.0001
year	1993	-0.696735836 B	0.05330414	-13.07	<.0001
year	1994	-0.374607551 B	0.05127235	-7.31	<.0001
year	1995	-0.079776565 B	0.05465402	-1.46	0.1445
year	1996	-0.015266111 B	0.05579885	-0.27	0.7844
year	1997	0.119306800 B	0.05442979	2.19	0.0285

Figure 12 Original multiplicative year, month, vessel and gear CPUE model for large vessels (>500 t) fishing for shrimp in Hawke Channel + 3K (SFA 6), 1989–2012-13, weighted by effort (single + double trawls, observer data, no windows, history > 3 years, standardized to 2012/13 values). The results came from the same model specifications used in the 2011 Northern Shrimp assessment

Parameter		Estimate		Standard Error	t Value	Pr > |t|
year	1998	-0.019985818	B	0.05037693	-0.40	0.6916
year	1999	-0.045198873	B	0.04880575	-0.93	0.3545
year	2000	0.083290020	B	0.04812121	1.73	0.0836
year	2001	0.091611437	B	0.04834330	1.90	0.0582
year	2002	-0.065882639	B	0.04682377	-1.41	0.1595
year	2003	-0.042419433	B	0.04802933	-0.88	0.3772
year	2004	0.011934089	B	0.04687966	0.25	0.7991
year	2005	0.020307289	B	0.04336923	0.47	0.6397
year	2006	0.132978508	B	0.04488483	2.96	0.0031
year	2007	0.054298864	B	0.04265096	1.27	0.2031
year	2008	0.011428613	B	0.04671144	0.24	0.8067
year	2009	-0.269562699	B	0.04887411	-5.52	<.0001
year	2010	-0.109780615	B	0.04231419	-2.59	0.0095
year	2011	-0.188670484	B	0.04398990	-4.29	<.0001
year	2012	0.000000000	B	.	.	.
month	1	0.366091716	B	0.03529307	10.37	<.0001
month	2	0.510450475	B	0.03233803	15.78	<.0001
month	3	0.421990041	B	0.03084911	13.68	<.0001
month	4	0.310521194	B	0.03136607	9.90	<.0001
month	5	0.095468773	B	0.03298327	2.89	0.0038
month	7	0.032350943	B	0.04145286	0.78	0.4352
month	8	0.058043034	B	0.04383624	1.32	0.1856
month	9	-0.017056668	B	0.04313430	-0.40	0.6926
month	10	0.054605438	B	0.04185153	1.30	0.1921
month	11	0.122135763	B	0.05699835	2.14	0.0322
month	12	-0.048695189	B	0.04092022	-1.19	0.2342
month	13	0.000000000	B	.	.	.
CFV		-0.076509788	B	0.05164272	-1.48	0.1386
CFV		0.311287383	B	0.04155613	7.49	<.0001
CFV		0.189665071	B	0.04004742	4.74	<.0001
CFV		0.020842516	B	0.04001167	0.52	0.6025
CFV		0.229013125	B	0.04564635	5.02	<.0001
CFV		0.102564384	B	0.06090332	1.68	0.0923
CFV		0.061333295	B	0.10851192	0.57	0.5720
CFV		0.089800005	B	0.03614786	2.48	0.0130
CFV		0.024084121	B	0.04481146	0.54	0.5910
CFV		0.209640505	B	0.03286808	6.38	<.0001
CFV		-0.074172202	B	0.04996151	-1.48	0.1378
CFV		0.033474933	B	0.04144776	0.81	0.4194
CFV		0.057133417	B	0.04094250	1.40	0.1630
CFV		0.124439970	B	0.08617929	1.44	0.1489
CFV		0.101701809	B	0.04958629	2.05	0.0404
CFV		0.170436231	B	0.05228077	3.26	0.0011
CFV		-0.361693398	B	0.05754937	-6.28	<.0001
CFV		0.252096956	B	0.04284827	5.88	<.0001
CFV		0.234293503	B	0.04090319	5.73	<.0001
CFV		0.326801510	B	0.03764177	8.68	<.0001
CFV		-0.188949292	B	0.03872351	-4.88	<.0001
CFV		-0.257644948	B	0.03589948	-7.18	<.0001
CFV		-0.520499571	B	0.04602680	-11.31	<.0001
CFV		-0.234371393	B	0.05856740	-4.00	<.0001

Figure 12 (Cont'd)

CFV		-0.080987996 B	0.08863325	-0.91	0.3609
CFV		0.000000000 B	.	.	.
gear	2	-0.242956031 B	0.02161926	-11.24	<.0001
gear	10	0.000000000 B	.	.	.
area	67	0.855413673 B	0.26517338	3.23	0.0013
area	68	0.792623168 B	0.26464476	3.00	0.0028
area	69	0.756073171 B	0.27387103	2.76	0.0058
area	80	0.935687814 B	0.26470525	3.53	0.0004
area	90	0.921547926 B	0.26516276	3.48	0.0005
area	92	0.000000000 B	.	.	.

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

year	lncpue LSMEAN	95 % Confidence Limits	
1989	5.758420	5.615415	5.901425
1990	6.001287	5.878891	6.123682
1991	6.341341	6.219610	6.463072
1992	6.425180	6.299112	6.551247
1993	6.603088	6.486613	6.719563
1994	6.925216	6.808118	7.042314
1995	7.220047	7.097818	7.342275
1996	7.284557	7.159803	7.409312
1997	7.419130	7.298038	7.540223
1998	7.279838	7.164435	7.395240
1999	7.254625	7.141571	7.367678
2000	7.383113	7.271348	7.494879
2001	7.391435	7.278438	7.504432
2002	7.233941	7.122934	7.344947
2003	7.257404	7.142689	7.372119
2004	7.311758	7.200706	7.422810
2005	7.320131	7.213749	7.426513
2006	7.432802	7.323257	7.542347
2007	7.354122	7.247989	7.460255
2008	7.311252	7.197708	7.424796
2009	7.030261	6.913587	7.146934
2010	7.190043	7.083013	7.297073
2011	7.111153	7.002174	7.220132
2012	7.299823	7.184847	7.414800

gear	lncpue LSMEAN	95 % Confidence Limits	
2	6.926021	6.833812	7.018229
10	7.168977	7.071251	7.266702

Figure 12 (Cont'd)

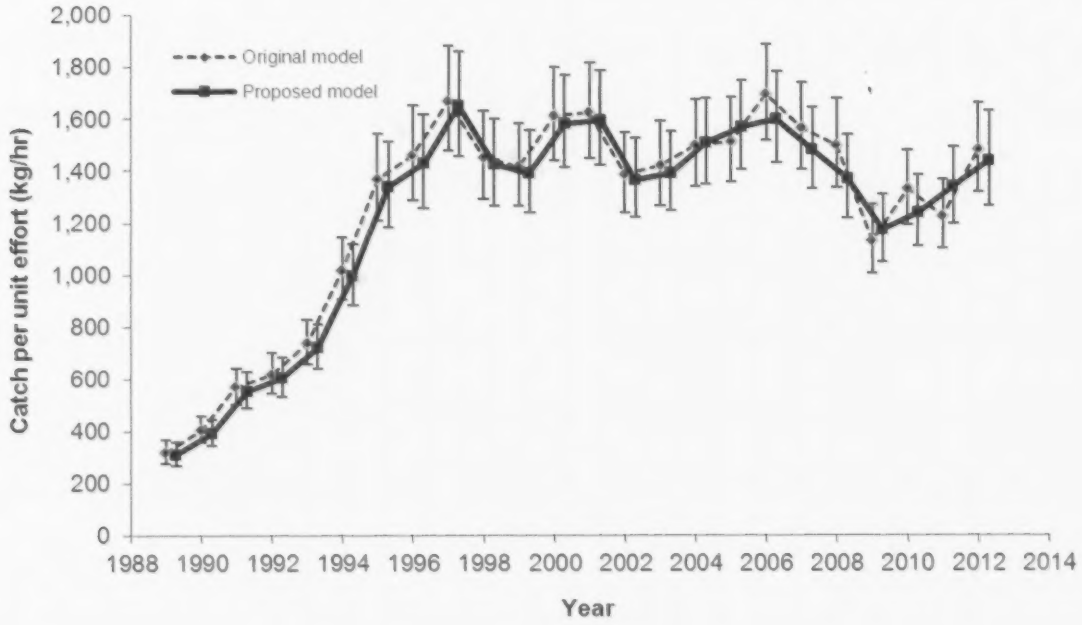


Figure 13 Overlay of original and proposed SFA 6 large vessel (>500 t) CPUE models (error bars indicate 95 % confidence intervals)

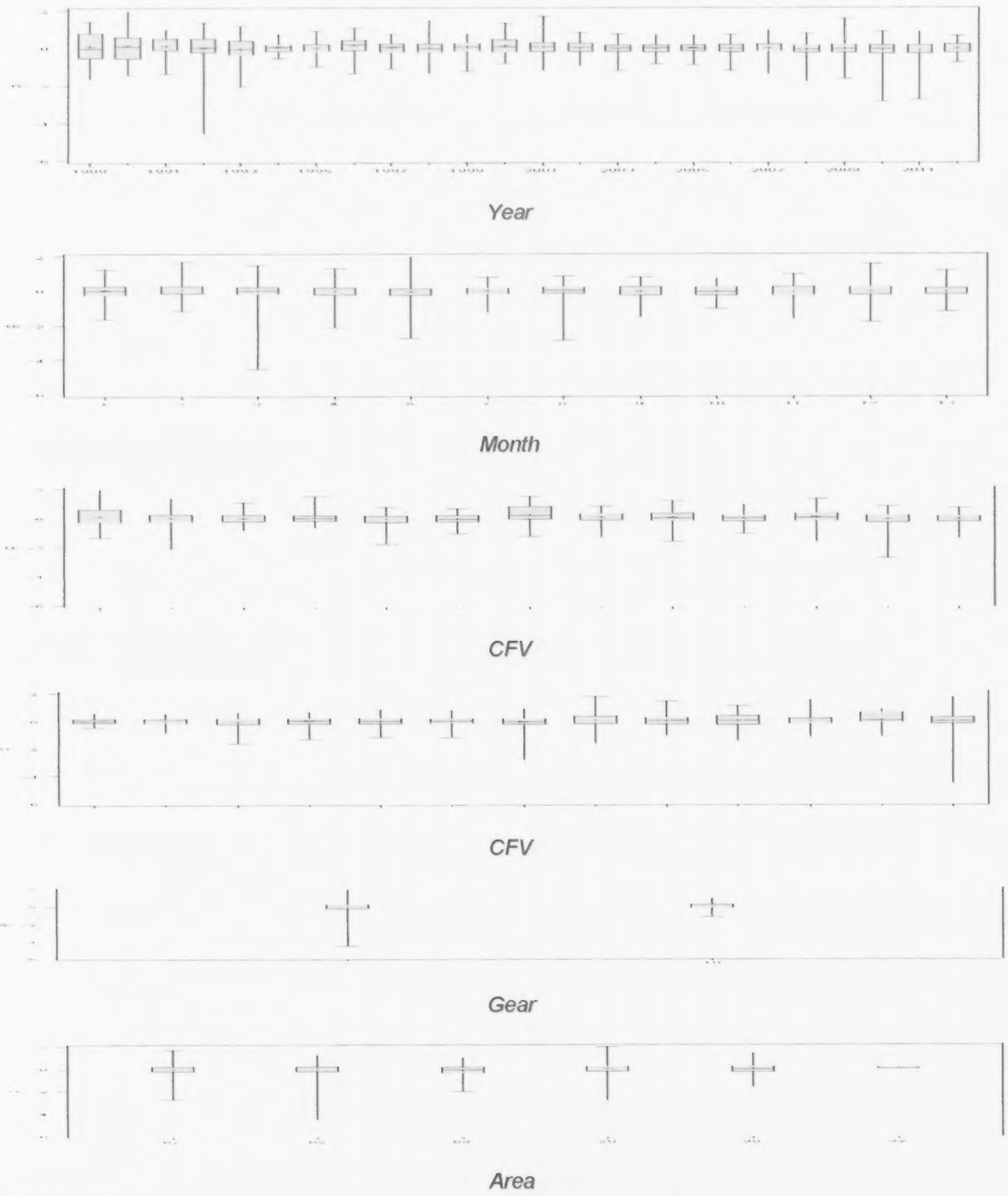


*Figure 14. Residuals around the **original** fishery performance model parameters for large vessels (>500 t) fishing shrimp in SFA 6 over the period 1989-2012.*

The GLM Procedure

Class Level Information

Class	Levels	Values
year	24	1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2020 Standardized to 1989 values.
month	12	1 2 4 5 6 7 8 9 10 11 12 13 Standardized to March values.
CFV	27	
gear	2	2 10 (Single trawl = 2; double trawl = 10)
area	6	67 68 69 80 90 92

Number of Observations Read 2487
Number of Observations Used 2487

Dependent Variable: lncpue
Weight: effort

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	66	50262.04069	761.55971	93.16	<.0001
Error	2420	19782.59918	8.17463		
Corrected Total	2486	70045.53987			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.717575	38.78007	2.859131	7.372680

Source	DF	Type I SS	Mean Square	F Value	Pr > F
year	23	33311.59769	1448.33033	177.17	<.0001
month	11	7045.78443	640.52586	78.36	<.0001
CFV	26	8395.73466	322.91287	39.50	<.0001
gear	1	911.57067	911.57067	111.51	<.0001
area	5	598.25325	119.65065	14.64	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	23	13863.66025	602.76784	73.74	<.0001
month	11	5495.96241	499.63295	61.12	<.0001
CFV	26	6187.57608	237.98370	29.11	<.0001
gear	1	1000.41999	1000.41999	122.38	<.0001
area	5	598.25325	119.65065	14.64	<.0001

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Intercept		5.405837031 B	0.27569244	19.61	<.0001
year	1990	0.242471575 B	0.07131770	3.40	0.0007
year	1991	0.584331891 B	0.06624071	8.82	<.0001
year	1992	0.671183364 B	0.06976956	9.62	<.0001
year	1993	0.847735494 B	0.06543949	12.95	<.0001
year	1994	1.171104618 B	0.06683813	17.52	<.0001
year	1995	1.467194334 B	0.06985964	21.00	<.0001
year	1996	1.532580401 B	0.07103306	21.58	<.0001
year	1997	1.676007894 B	0.06970724	24.04	<.0001
year	1998	1.529630403 B	0.06665673	22.95	<.0001
year	1999	1.504490815 B	0.06538553	23.01	<.0001
year	2000	1.635233670 B	0.06538999	25.01	<.0001
year	2001	1.643513851 B	0.06599183	24.90	<.0001
year	2002	1.488087818 B	0.06573312	22.64	<.0001
year	2003	1.505957062 B	0.06391505	23.56	<.0001
year	2004	1.585502543 B	0.06477520	24.48	<.0001

Figure 15 Proposed multiplicative year, month, vessel and area CPUE model for large vessels (>500 t) fishing for shrimp in Hawke Channel + 3K (SFA 6), 1989-2012-13, weighted by effort (Single + double trawl, observer data, no windows, history > 3 years). The model has been standardized to the first year and after 2002 data were converted from calendar year to management year

Parameter		Estimate		Standard Error	t Value	Pr > |t|
year	*2005*	*1.624852416*	*B*	*0.06589889*	*24.66*	*<.0001*
year	2006	1.644879592	B	0.06515731	25.24	<.0001
year	2007	1.567676921	B	0.06418214	24.43	<.0001
year	2008	1.490086029	B	0.06850664	21.75	<.0001
year	2009	1.333950649	B	0.06624971	20.14	<.0001
year	2010	1.389446358	B	0.06678901	20.80	<.0001
year	2011	1.466688353	B	0.06635883	22.10	<.0001
year	2012	1.539991577	B	0.07265408	21.20	<.0001
year	2020	0.000000000	B	.	.	.
month	1	-0.057444046	B	0.02628204	-2.19	0.0289
month	2	0.083987440	B	0.02288016	3.67	0.0002
month	4	-0.115104342	B	0.02277233	-5.05	<.0001
month	5	-0.327698693	B	0.02612931	-12.54	<.0001
month	6	-0.423105391	B	0.03104103	-13.63	<.0001
month	7	-0.399478220	B	0.03817597	-10.46	<.0001
month	8	-0.379830561	B	0.03957985	-9.60	<.0001
month	9	-0.443555817	B	0.03907318	-11.35	<.0001
month	10	-0.400018615	B	0.03692247	-10.83	<.0001
month	11	-0.334765703	B	0.05312181	-6.30	<.0001
month	12	-0.479534711	B	0.03508420	-13.67	<.0001
month	13	0.000000000	B	.	.	.
CFV		-0.080392754	B	0.05213950	-1.54	0.1232
CFV		0.306942580	B	0.04198167	7.31	<.0001
CFV		0.184175328	B	0.04046156	4.55	<.0001
CFV		0.016100462	B	0.04043938	0.40	0.6906
CFV		0.216447872	B	0.04625280	4.68	<.0001
CFV		0.114743438	B	0.06136977	1.87	0.0616
CFV		0.059278744	B	0.10959328	0.54	0.5886
CFV		0.085344096	B	0.03650950	2.34	0.0195
CFV		0.019014057	B	0.04530013	0.42	0.6747
CFV		0.206565892	B	0.03332620	6.20	<.0001
CFV		-0.078069412	B	0.05046560	-1.55	0.1220
CFV		0.030953629	B	0.04180781	0.74	0.4591
CFV		0.046027156	B	0.04166117	1.10	0.2694
CFV		0.125015182	B	0.08631438	1.45	0.1476
CFV		0.096607948	B	0.05011645	1.93	0.0540
CFV		0.145166536	B	0.05313726	2.73	0.0063
CFV		-0.364077557	B	0.05814348	-6.26	<.0001
CFV		0.235553933	B	0.04322100	5.45	<.0001
CFV		0.241683313	B	0.04120516	5.87	<.0001
CFV		0.336820536	B	0.03808791	8.84	<.0001
CFV		-0.193035291	B	0.03915297	-4.93	<.0001
CFV		-0.262671964	B	0.03612831	-7.27	<.0001
CFV		-0.529205300	B	0.04652847	-11.37	<.0001
CFV		-0.236850753	B	0.05919165	-4.00	<.0001
CFV		-0.355019832	B	0.09639577	-3.68	0.0002
CFV		-0.084383697	B	0.08948135	-0.94	0.3458
CFV		0.000000000	B	.	.	.

Figure 15 (Cont'd)

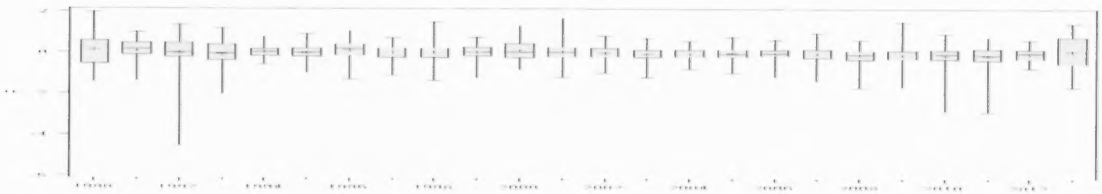
Parameter		Estimate		Standard Error	t Value	Pr > |t|
gear	2	-0.240429743	B	0.02173357	-11.06	<.0001
gear	10	0.000000000	B	.	.	.
area	67	0.847711468	B	0.26778795	3.17	0.0016
area	68	0.796141609	B	0.26725890	2.98	0.0029
area	69	0.745902509	B	0.27602312	2.70	0.0069
area	80	0.931900536	B	0.26734723	3.49	0.0005
area	90	0.924127581	B	0.26779761	3.45	0.0006
area	92	0.000000000	B	.	.	.

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

year	lncpue LSMEAN	95% Confidence Limits	
1990	5.973150	5.849431	6.096869
1991	6.315011	6.191934	6.438087
1992	6.401862	6.274484	6.529240
1993	6.578414	6.460524	6.696304
1994	6.901783	6.783394	7.020172
1995	7.197873	7.074284	7.321462
1996	7.263259	7.137148	7.389370
1997	7.406687	7.284354	7.529019
1998	7.260309	7.143722	7.376896
1999	7.235170	7.120994	7.349345
2000	7.365912	7.253125	7.478700
2001	7.374193	7.260126	7.488259
2002	7.218767	7.106788	7.330745
2003	7.236636	7.127603	7.345669
2004	7.316181	7.207264	7.425099
2005	7.355531	7.245660	7.465403
2006	7.375558	7.265837	7.485280
2007	7.298356	7.191434	7.405277
2008	7.220765	7.104409	7.337120
2009	7.064629	6.953859	7.175399
2010	7.120125	7.009293	7.230957
2011	7.197367	7.087615	7.307120
2012	7.270670	7.144545	7.396795
2020	5.730679	5.586161	5.875197

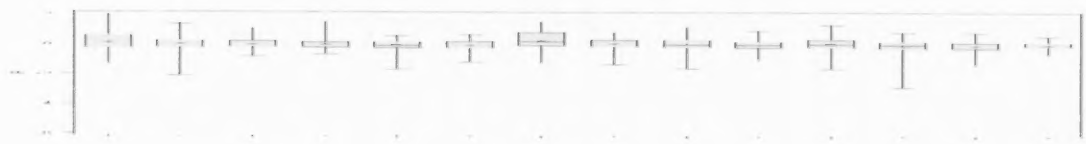
gear	lncpue LSMEAN	95% Confidence Limits	
2	6.908072	6.815174	7.000970
10	7.148502	7.049946	7.24705

Figure 15 (Cont'd)



Year

Month



CFV

CFV

Gear

Area

*Figure 16 Residuals around the **proposed** fishery performance model parameters for large vessels (>500 t) fishing shrimp in SFA 6 over the period 1989-2012-13*

The GLM Procedure

Class Level Information

Class	Levels	Values
Year	15	1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2020 Standardized to 1998
Month	9	4 5 6 8 9 10 11 12 13 Standardized to July
size_class	3	1 2 3
Area	7	67 68 80 90 91 92 100 Standardized to area 69

Number of Observations Read 1424
Number of Observations Used 1369

Dependent Variable: lncpue
Weight: effort

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	30	65859.04605	2195.30154	90.19	<.0001
Error	1338	32568.28172	24.34102		
Corrected Total	1368	98427.32777			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.669113	81.33043	4.933662	6.066194

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Year	14	50046.40126	3574.74295	146.86	<.0001
Month	8	4929.64306	616.20538	25.32	<.0001
size_class	2	7300.32554	3650.16277	149.96	<.0001
Area	6	3582.67619	597.11270	24.53	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Year	14	33866.17922	2419.01280	99.38	<.0001
Month	8	6613.34245	826.66781	33.96	<.0001
size_class	2	7145.59995	3572.79998	146.78	<.0001
Area	6	3582.67619	597.11270	24.53	<.0001

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Intercept		5.978345736 B	0.02459277	243.09	<.0001
Year	1999	-0.002528017 B	0.02600222	-0.10	0.9226
Year	2000	0.145947382 B	0.02597549	5.62	<.0001
Year	2001	0.146764085 B	0.02707373	5.42	<.0001
Year	2002	0.031043435 B	0.02513556	1.24	0.2170
Year	2003	0.043321549 B	0.02511588	1.72	0.0848
Year	2004	0.407580261 B	0.02630886	15.49	<.0001
Year	2005	0.461136479 B	0.02706796	17.04	<.0001
Year	2006	0.465685437 B	0.02696585	17.27	<.0001
Year	2007	0.508386921 B	0.02697676	18.85	<.0001
Year	2008	0.396398208 B	0.02568544	15.43	<.0001
Year	2009	0.168771202 B	0.02857567	5.91	<.0001

Figure 17 Multiplicative year, month, vessel size and area CPUE model for small vessels (<=500 t; LOA<= 100') fishing in SFA 6 weighted by effort (logbook data, history > 3 yrs.; standardized to 1998). The vessel size classes were as follows: LOA<= 50'; 50'<LOA<=60' and 60'<=LOA

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Year	2010	0.287433206 B	0.02741327	10.49	<.0001
Year	2011	0.350480408 B	0.02821358	12.42	<.0001
Year	2012	0.357970485 B	0.02990094	11.97	<.0001
Year	2020	0.000000000 B	.	.	.
Month	4	-0.044569866 B	0.04790057	-0.93	0.3523
Month	5	-0.089181504 B	0.01921225	-4.64	<.0001
Month	6	-0.092500905 B	0.01445975	-6.40	<.0001
Month	8	0.024691118 B	0.01292777	1.91	0.0564
Month	9	-0.082796974 B	0.01478017	-5.60	<.0001
Month	10	-0.201842639 B	0.01892947	-10.66	<.0001
Month	11	-0.288942360 B	0.03728963	-7.75	<.0001
Month	12	-0.994054065 B	0.15100713	-6.58	<.0001
Month	13	0.000000000 B	.	.	.
size_class	1	-0.258270690 B	0.01690745	-15.28	<.0001
size_class	2	-0.108262235 B	0.00945286	-11.45	<.0001
size_class	3	0.000000000 B	.	.	.
Area	67	0.070696906 B	0.02135826	3.31	0.0010
Area	68	0.117689806 B	0.04231617	2.78	0.0055
Area	80	-0.023176458 B	0.01660002	-1.40	0.1629
Area	90	-0.126168162 B	0.01614089	-7.82	<.0001
Area	91	0.066496173 B	0.03847205	1.73	0.0841
Area	92	-0.083948369 B	0.01173880	-7.15	<.0001
Area	100	0.000000000 B	.	.	.

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

yearf	lncpue LSMEAN	95% Confidence Limits	
1999	5.660147	5.608053	5.712240
2000	5.808622	5.758166	5.859078
2001	5.809439	5.756846	5.862032
2002	5.693718	5.645220	5.742216
2003	5.705996	5.657363	5.754630
2004	6.070255	6.018013	6.122497
2005	6.123811	6.070284	6.177338
2006	6.128360	6.075360	6.181360
2007	6.171062	6.118243	6.223881
2008	6.059073	6.008494	6.109652
2009	5.831446	5.774675	5.888217
2010	5.950108	5.895989	6.004227
2011	6.013155	5.957741	6.068570
2012	6.020645	5.961474	6.079817
2020	5.662675	5.609570	5.715780

size_class	lncpue LSMEAN	95% Confidence Limits	
1	5.777808	5.727479	5.828137
2	5.927816	5.886617	5.969016
3	6.036079	5.996597	6.07556

Figure 17 (Cont'd)

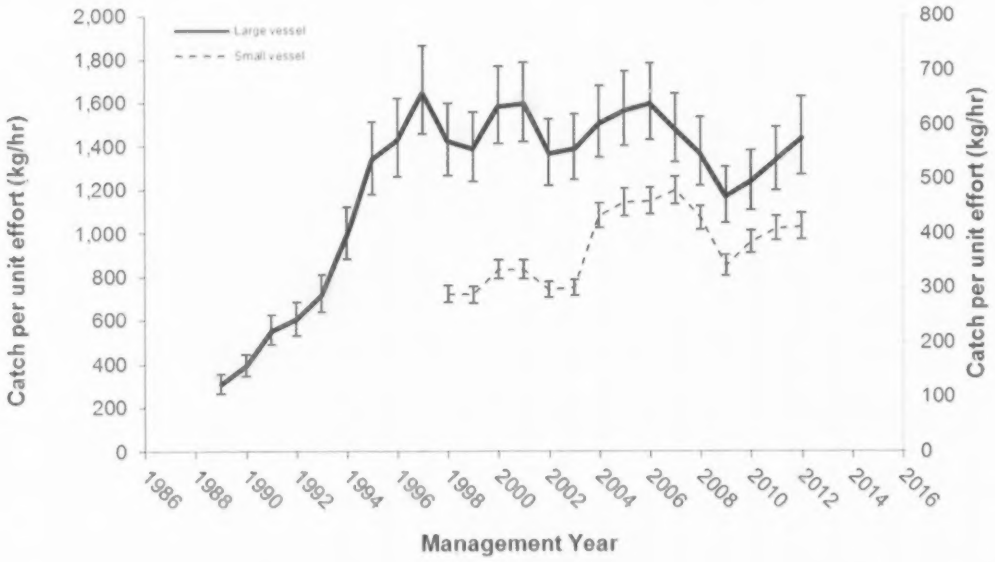


Figure 18 Overlay of proposed large (>500 t) and small (<=500 t; LOA<100') vessel CPUE models (error bars indicate 95 % confidence intervals) for the Northern Shrimp fishery in SFA 6

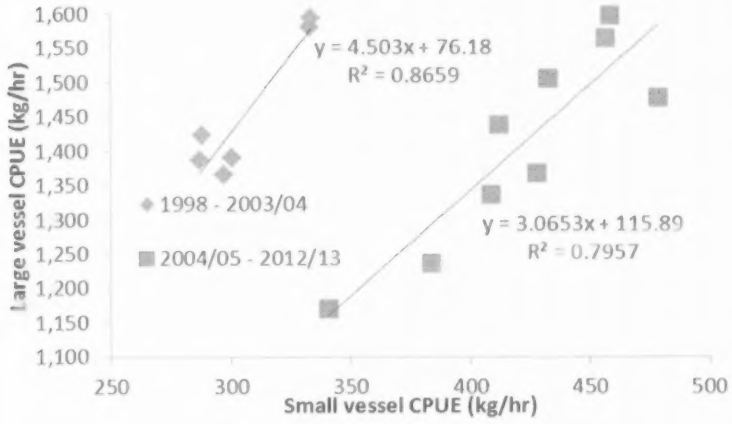
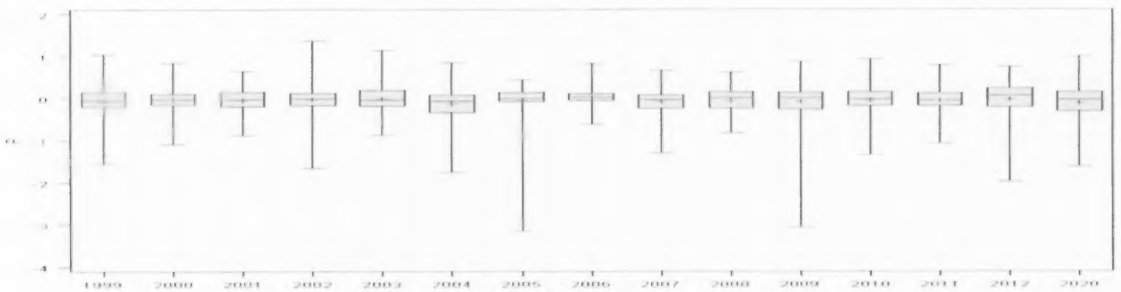
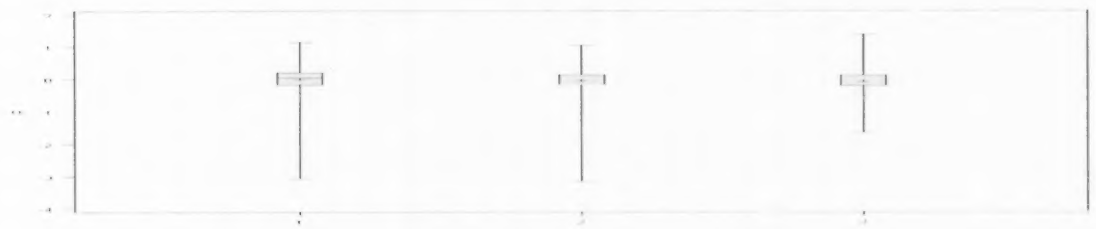


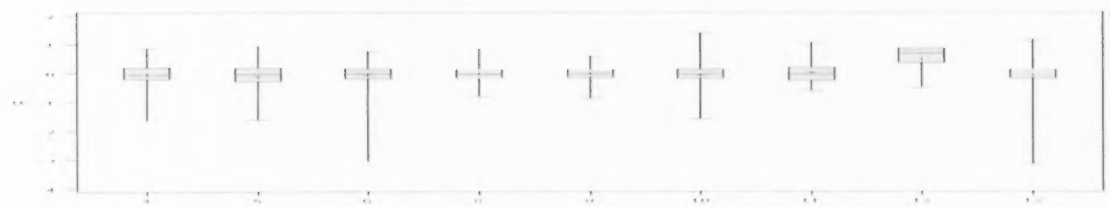
Figure 19 Simple regression relationships between SFA 6 small and large vessel catch rate estimates



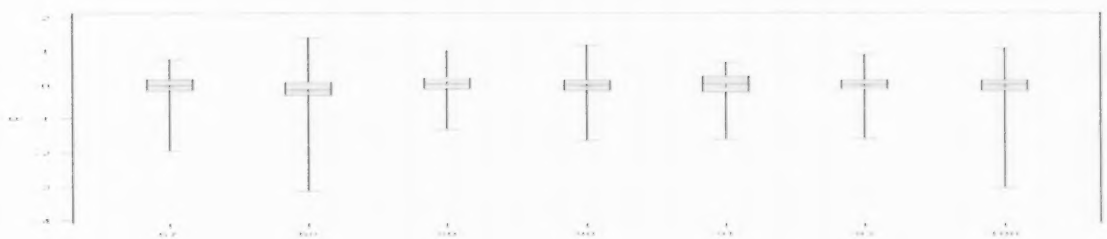
Year



Size class



Month



Area

Figure 20 Residuals around the fishery performance model parameters for small vessels (<=500 t; LOA<100') fishing shrimp in SFA 6 over the period 1998-2012

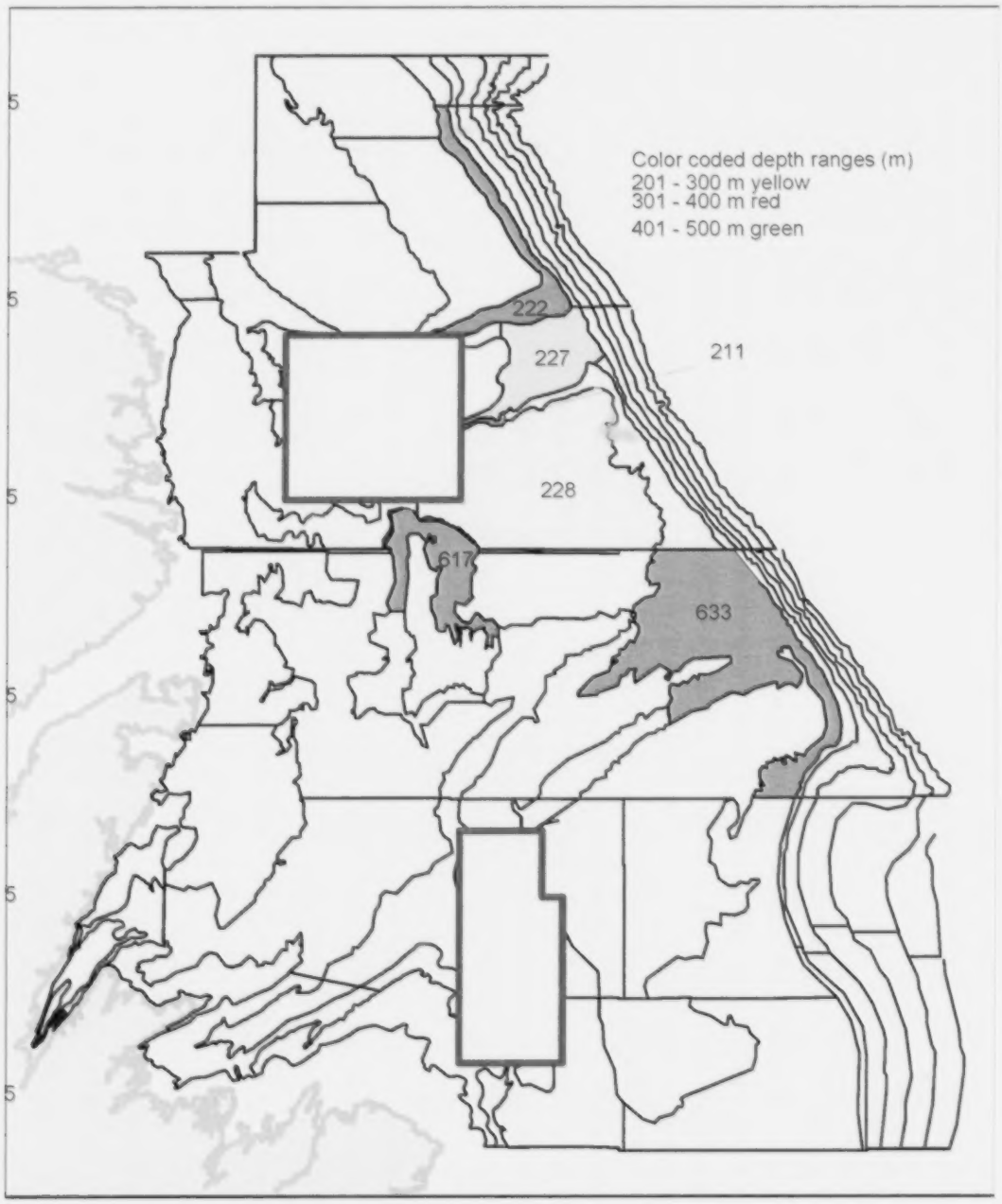


Figure 21 Index strata within SFA 6 that were consistently fished by the large vessel fleet, over the period 1992-2012-13. The numbers indicate the index strata within Tables 9 and 11

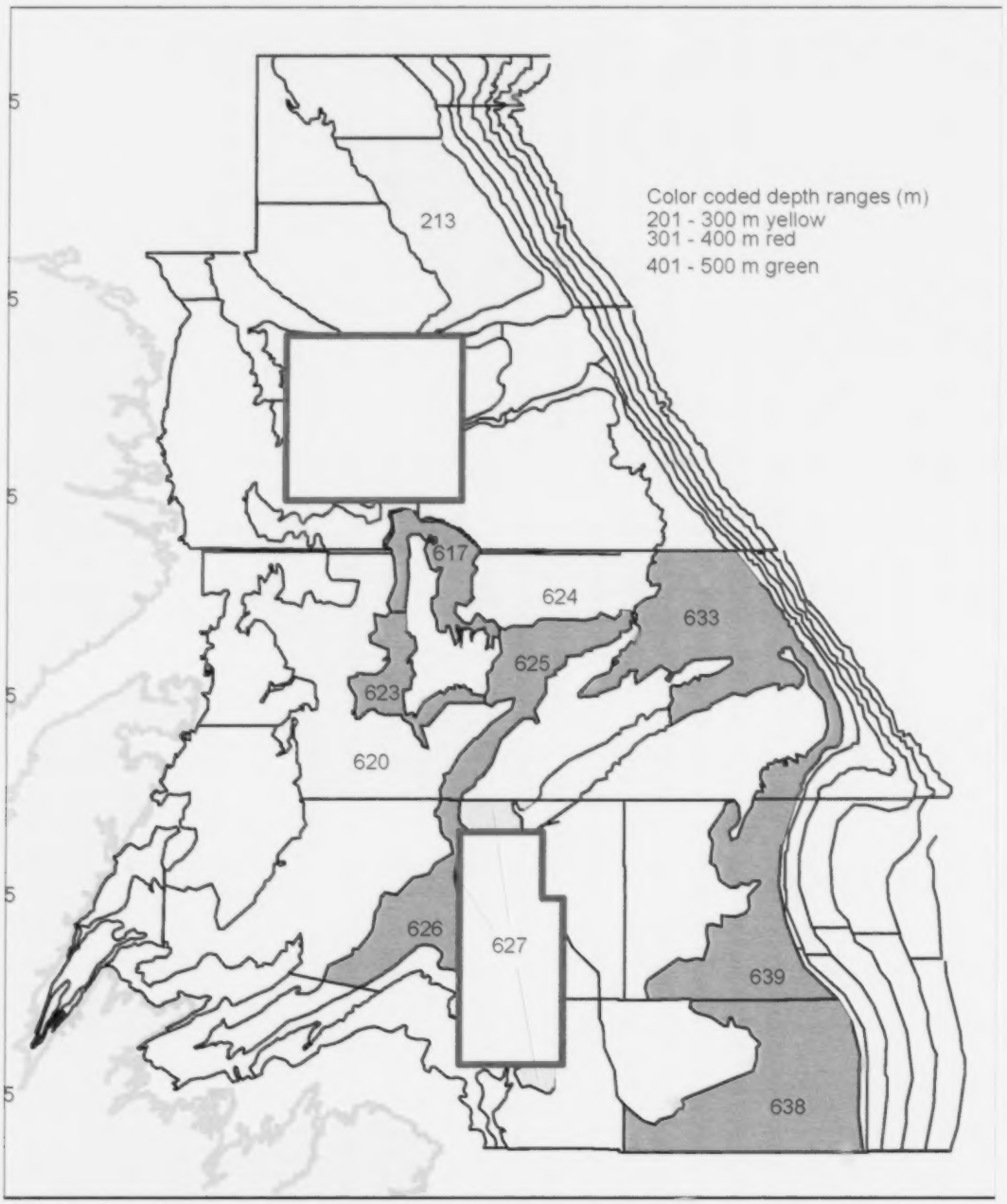


Figure 22 Index strata within SFA 6 that were consistently fished by the small vessel fleet, over the period 1998-2012-13. The numbers indicate the index strata within Tables 12 and 14

Figure 23 Observed northern shrimp length frequencies (per 000) from the Canadian large vessel (>500 t) fleet fishing shrimp in Hawke Channel + 3K (SFA 6) over the period 2003-12. Solid lines = males; dotted lines = females. These length frequencies are based upon management year data.

Figure 24 Observed Northern Shrimp length frequencies (per 000) from the Canadian small vessel (<=500 t; <100' LOA) fleet fishing shrimp in Hawke Channel + 3K (SFA 6) over the period 2003-12. Solid lines = non ovigerous animals; dotted lines = ovigerous animals. These length frequencies are based upon management year data

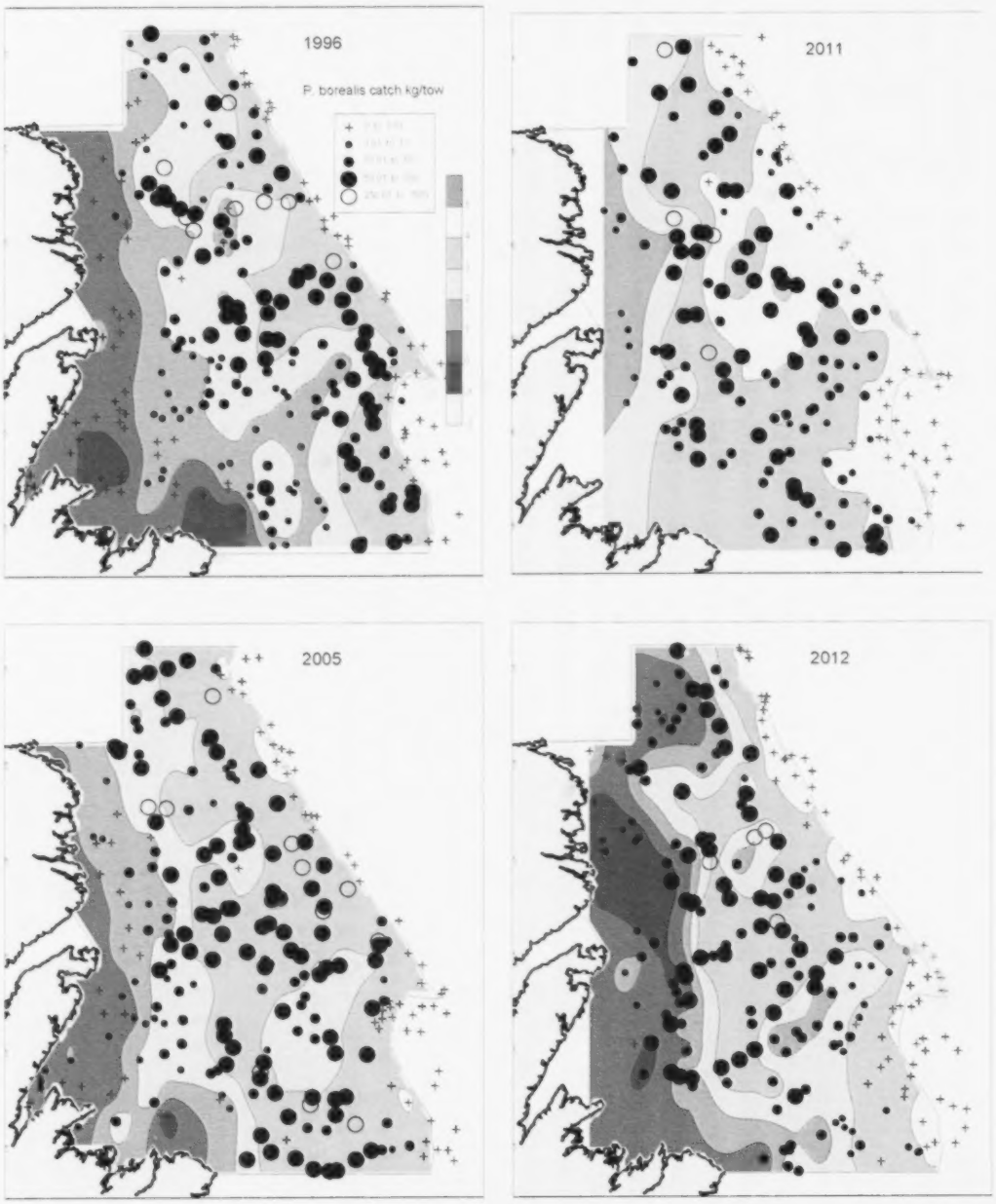


Figure 25 Overlay of SFA 6 Northern Shrimp (Pandalus borealis) catches (kg/tow) upon bottom temperatures as obtained from the autumn research bottom trawl surveys conducted over the period 1996-2012

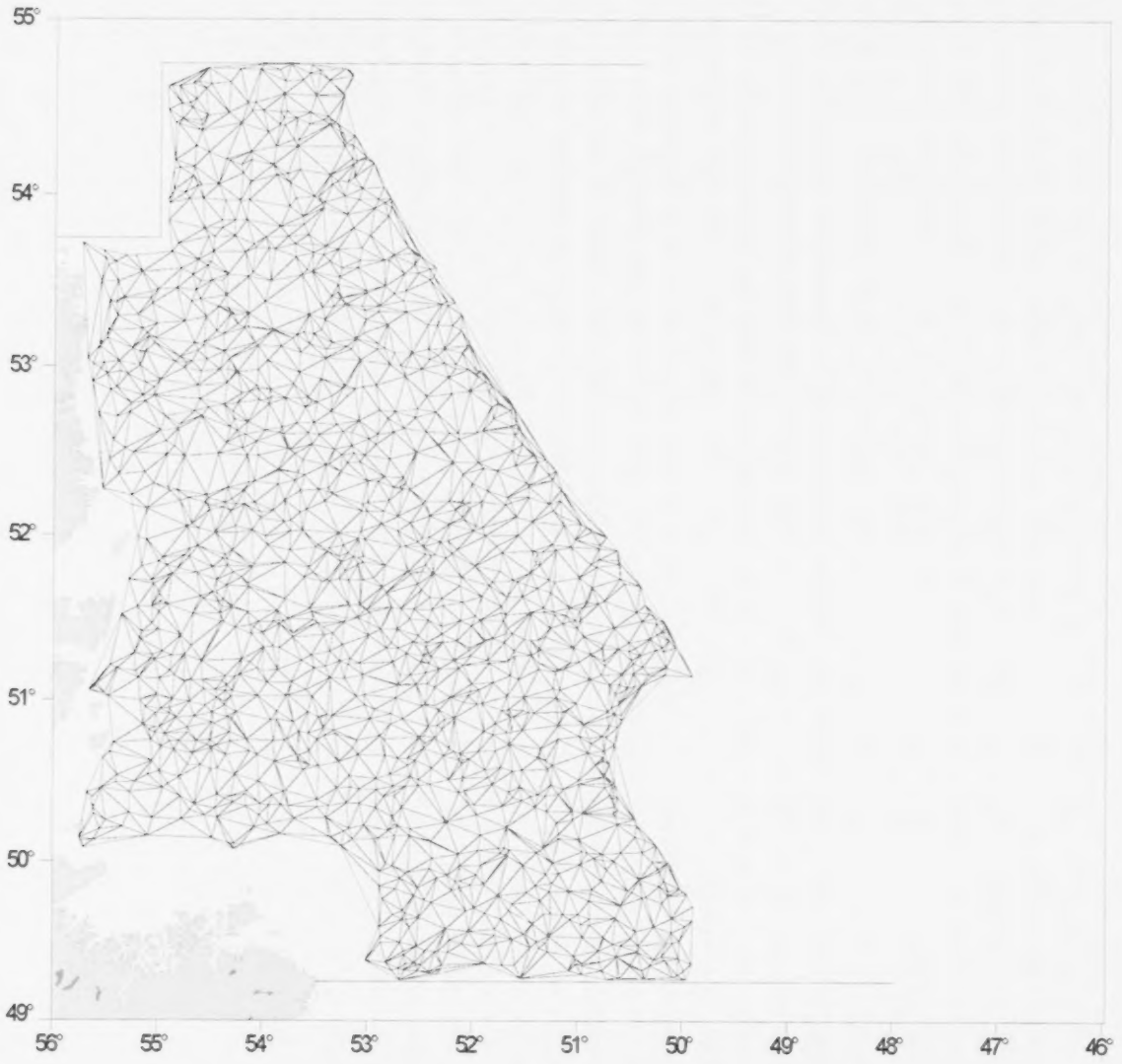


Figure 26 SFA 6 Delauney triangulations used in the Ogive Mapping calculations of survey indices

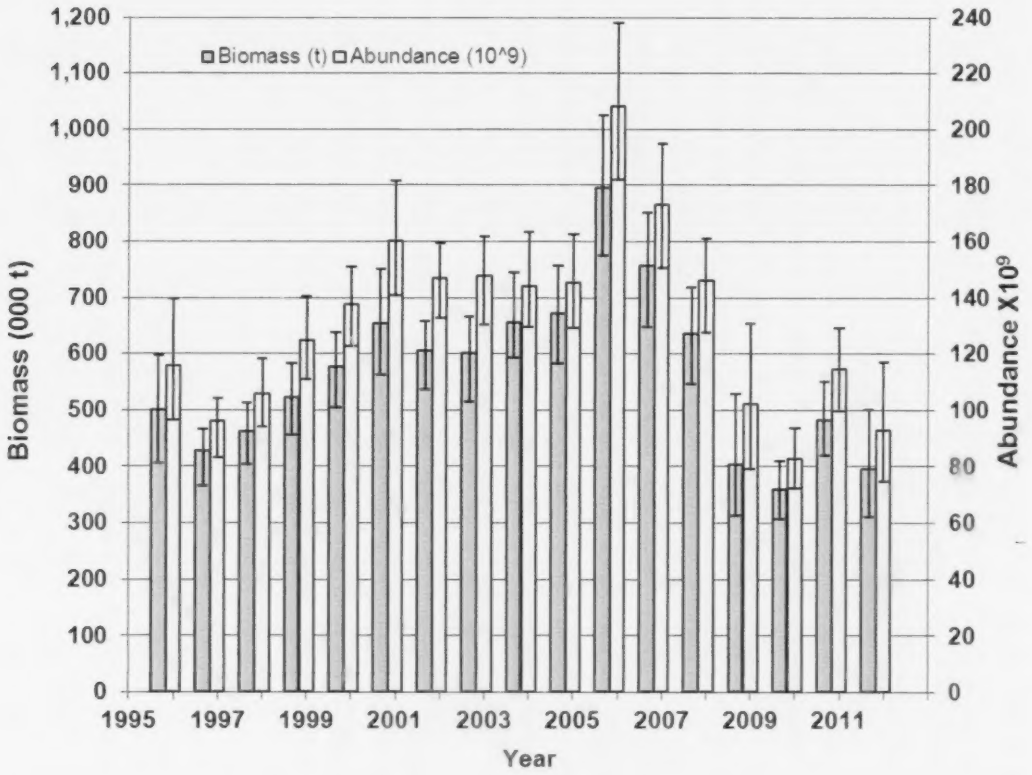


Figure 27 Autumn Northern Shrimp (Pandalus borealis) biomass and abundance indices within Hawke Channel + 3K (SFA 6), as determined using Ogive Mapping calculations

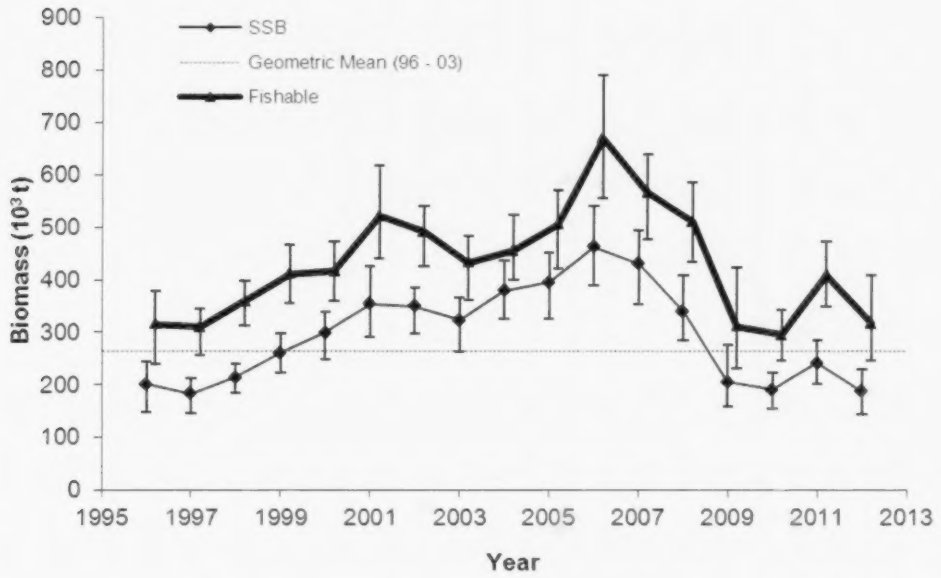


Figure 28 SFA 6 biomass indices (error bars indicate 95 % confidence intervals). The dotted line is the geometric mean of SSB over the years 1996-2003 and is used as a proxy for B_{MSY}

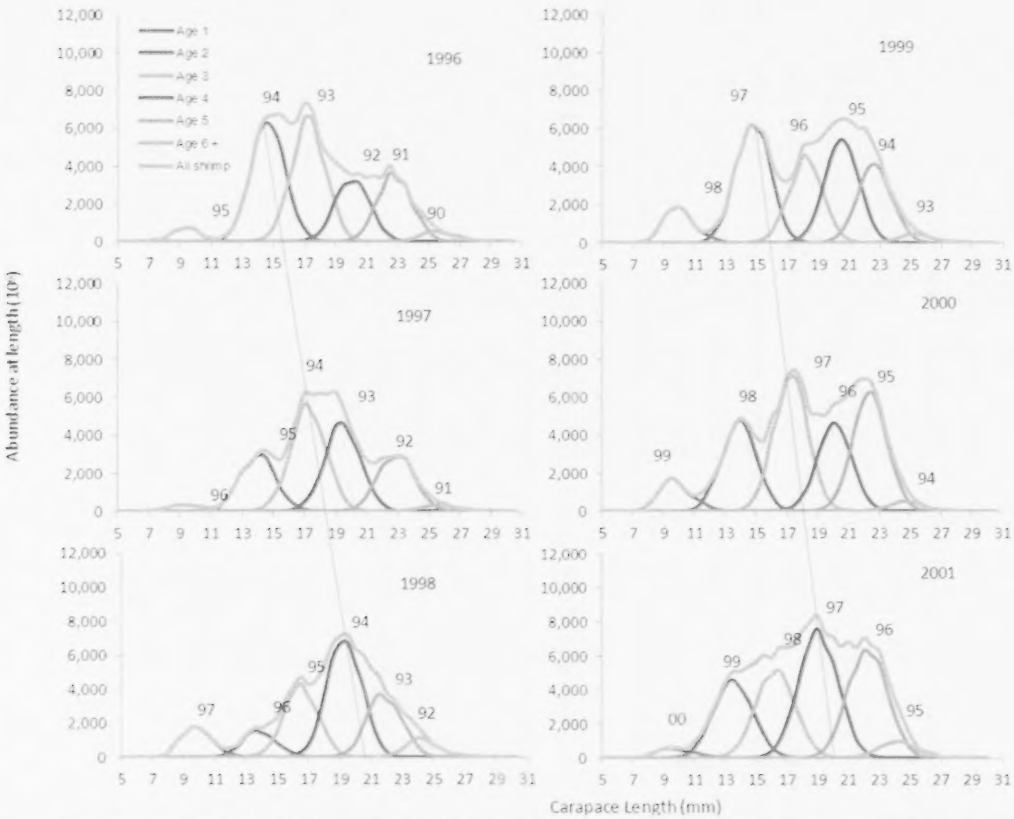


Figure 29 Abundance at length for Hawke Channel + 3K (SFA 6) Northern Shrimp (Pandalus borealis) estimated from Ogive Mapping calculations of autumn multi-species bottom trawl survey data, 1996-2012. The numbers indicate cohorts while the lines indicate that strong cohorts can be tracked from one year to the next

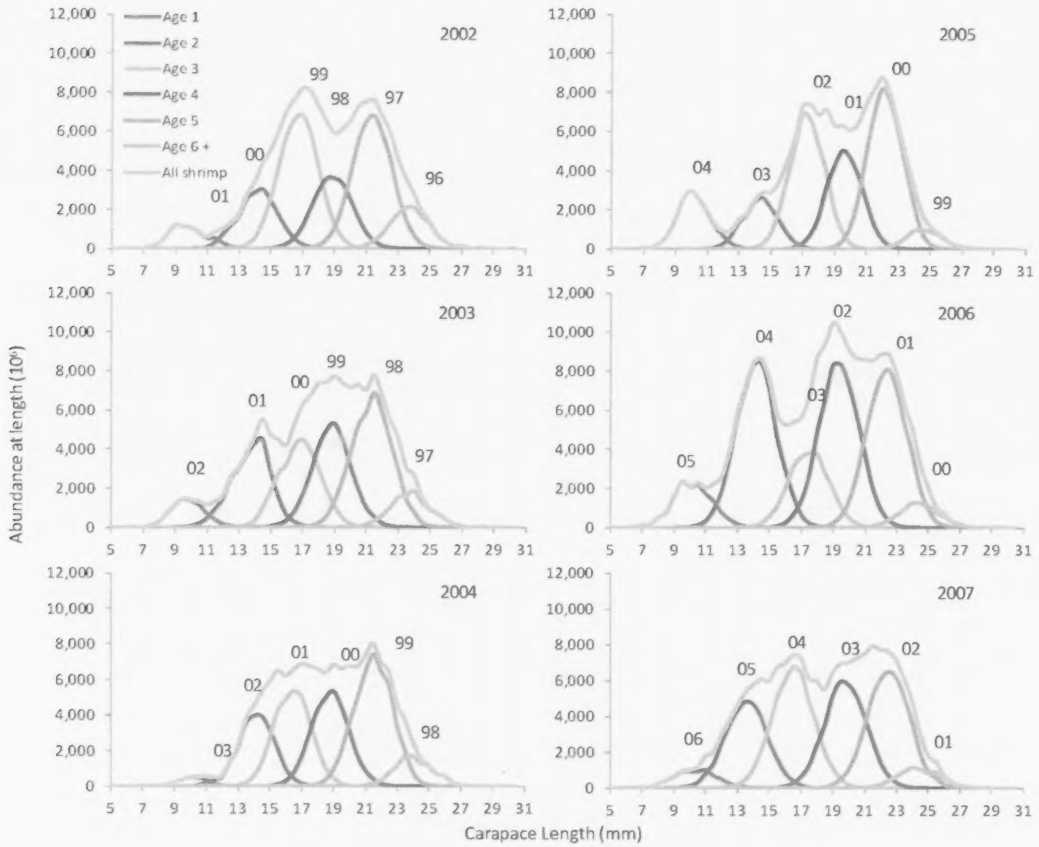


Figure 29 (Cont'd.)

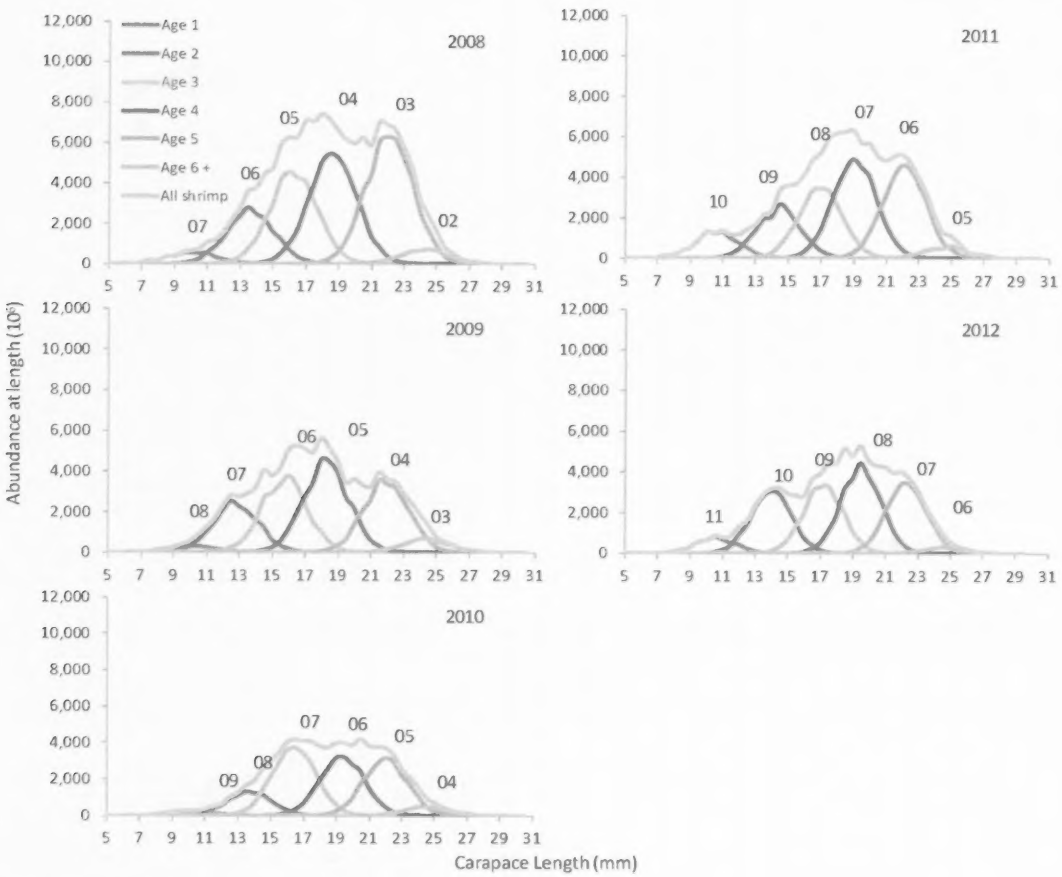


Figure 29 (Cont'd.)

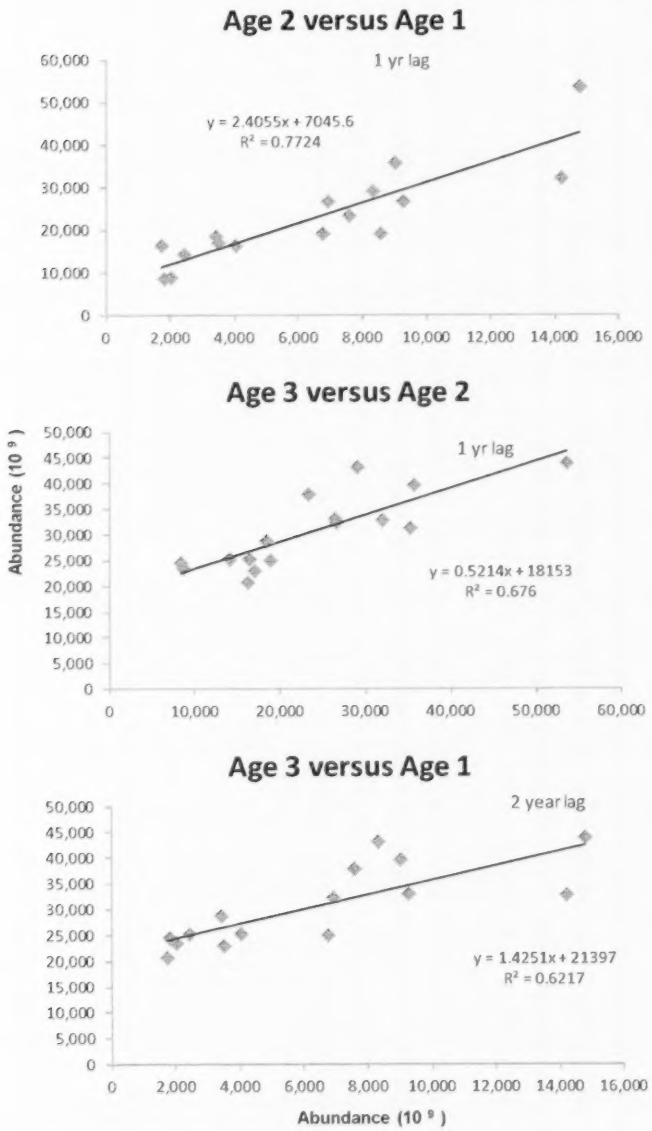


Figure 30 SFA 6 relationships between abundances at age with appropriate lags. Abundances at age were determined by modal analysis

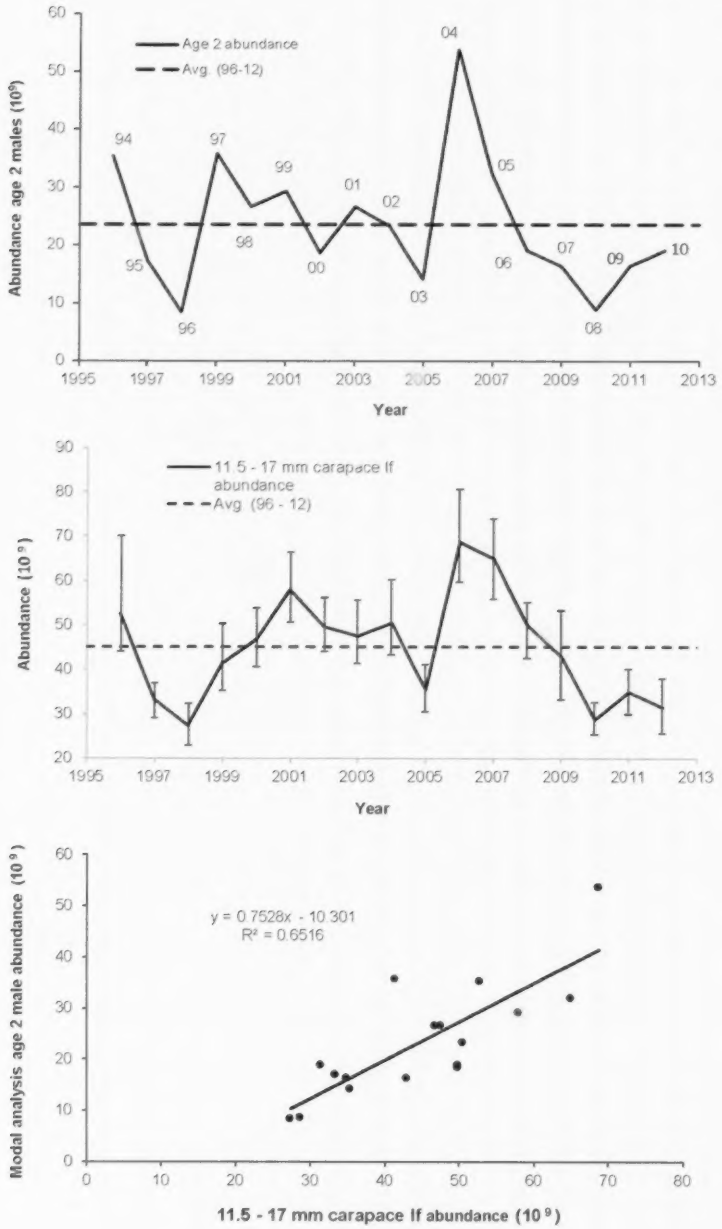

Age 2 abundance
Avg. (96-12)
Abundance age 2 males (10⁹)
Year
11.5 - 17 mm carapace If abundance
Avg. (96 - 12)
Abundance (10⁹)
Year
y = 0.7528x - 10.301
R² = 0.6516
Modal analysis age 2 male abundance (10⁹)
11.5 - 17 mm carapace If abundance (10⁹)

Figure 31 SFA 6 Northern Shrimp recruitment indices defined as abundances of age 2 shrimp from modal analysis and 11.5-17 mm carapace lf animals of both sexes with the relationship between the two indices. The numbers within the upper panel (age 2 abundance) denote the year in which a cohort was hatched

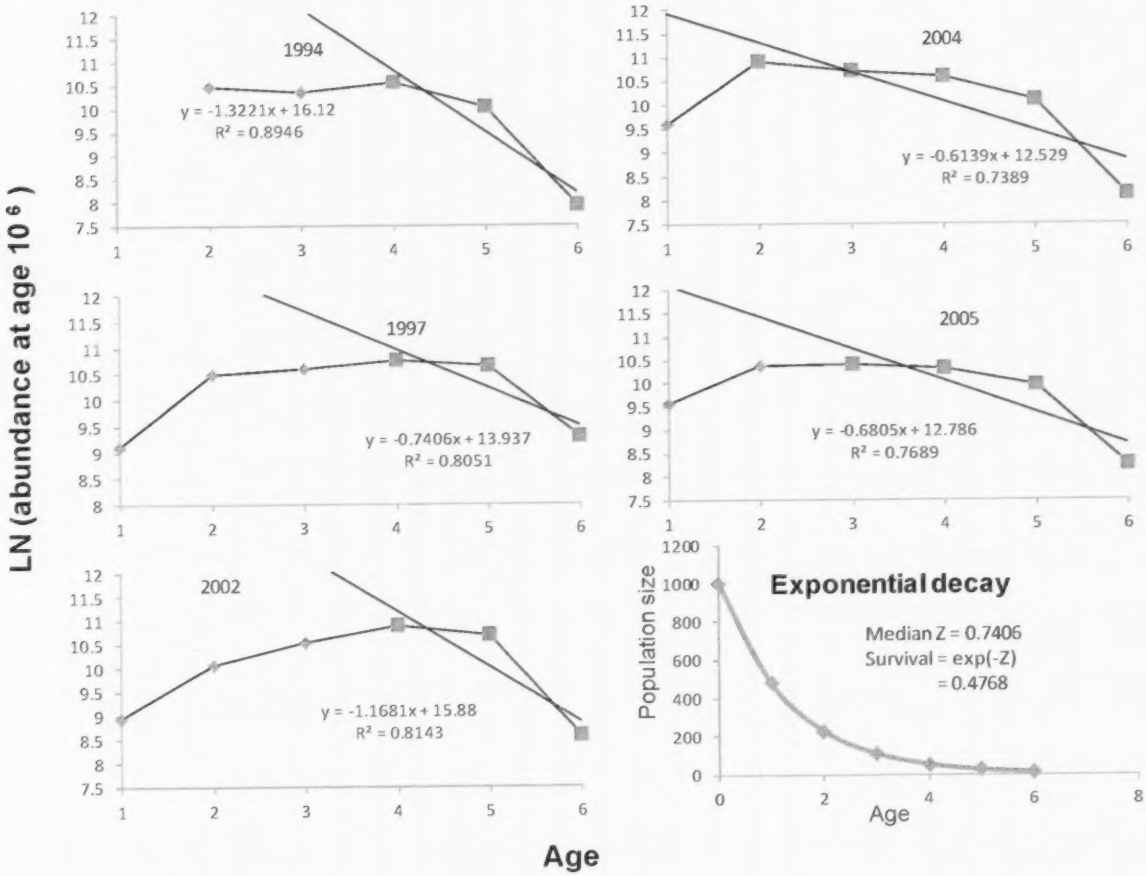


Figure 32 Total instantaneous mortality as determined from catch curve analysis of SFA 6 Northern shrimp. Each panel is from data from cohorts that were strong enough to be tracked through their life span (see Figure 26)

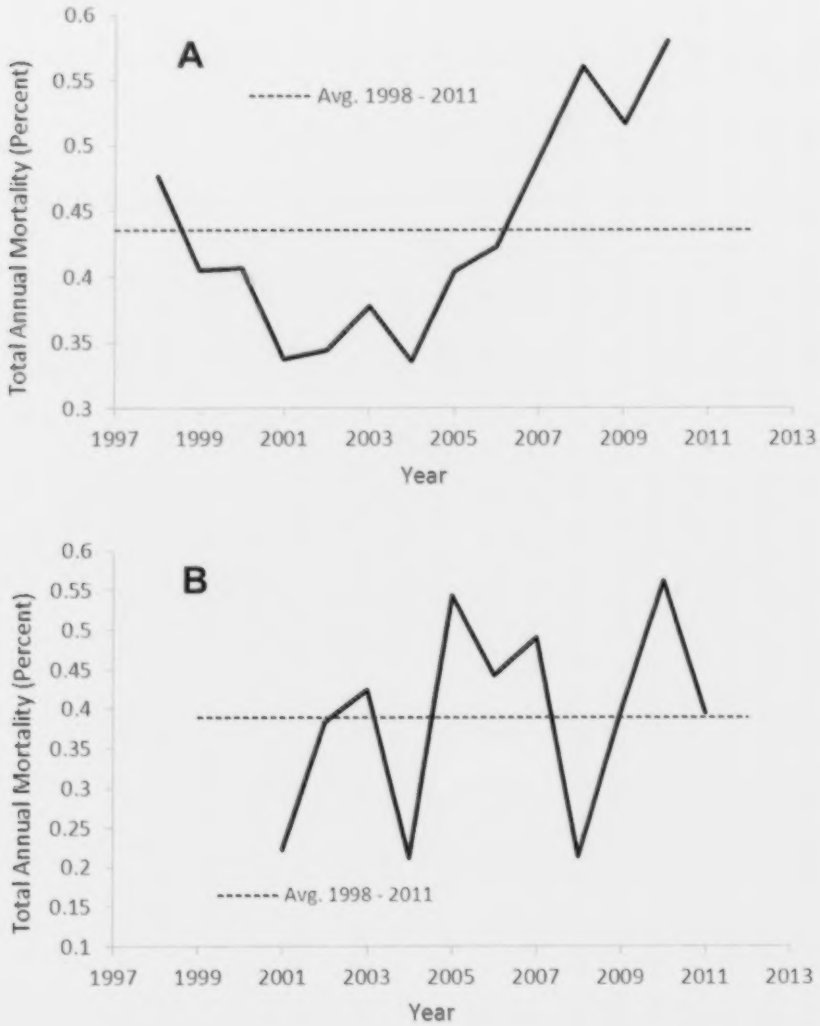


Figure 33 SFA 6 total annual mortality as determined from survival of age 4+ shrimp in one year to the next (A) as age 5+ shrimp and survival of females (primiparous + multiparous) to the next year as multiparous animals (B). In both cases, data have been averaged over four years. Year on the x-axis is the third year of the four year period

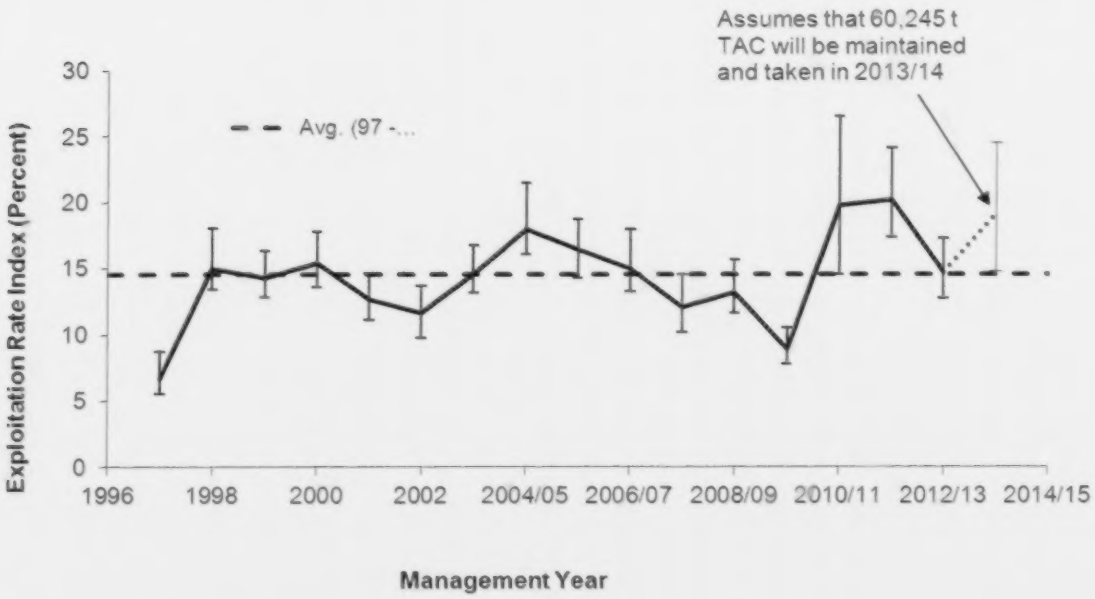


Figure 34 SFA 6 exploitation rate index based on the total catch/ fishable biomass index from the previous year, expressed as a percentage. Error bars indicate 95 % confidence intervals. The 2012-13 value is preliminary as the fishery was ongoing. The 2013-14 exploitation rate index assumes that the 2012-13 TAC of 60,245 t will be maintained through 2013-14

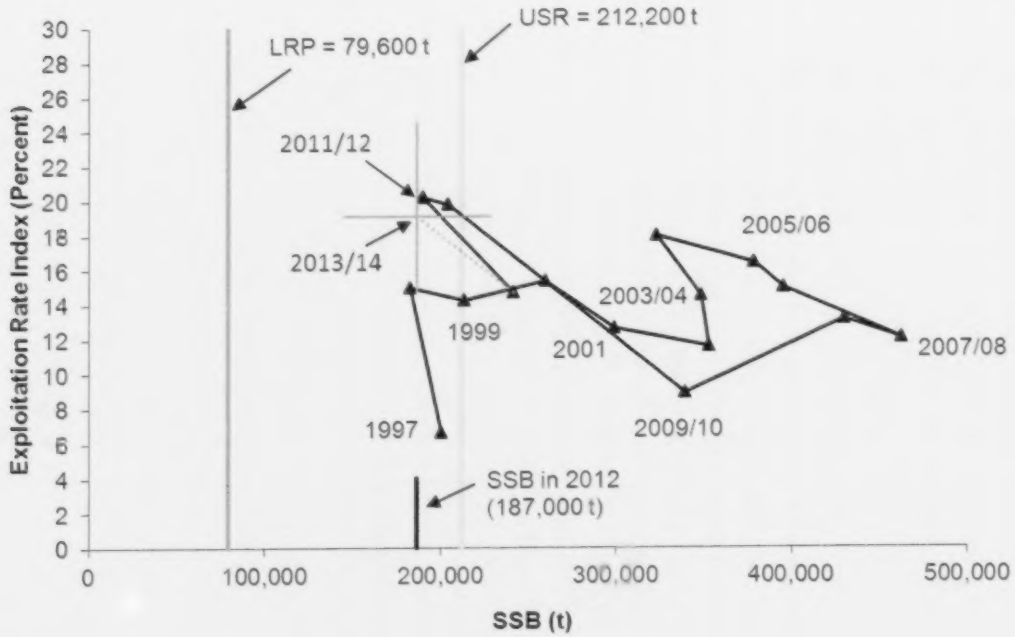


Figure 35 SFA 6 Precautionary Approach framework with trajectory of exploitation rate index vs. SSB. Numbers denote management year. The 2012-13 fishery was ongoing therefore the catch was set equal to the TAC. The red cross indicates the 95 % confidence interval for the autumn 2012 SSB (horizontal bar), and the exploitation rate if the 2012-13 TAC of 60,245 t is maintained (vertical bar) through 2013-14

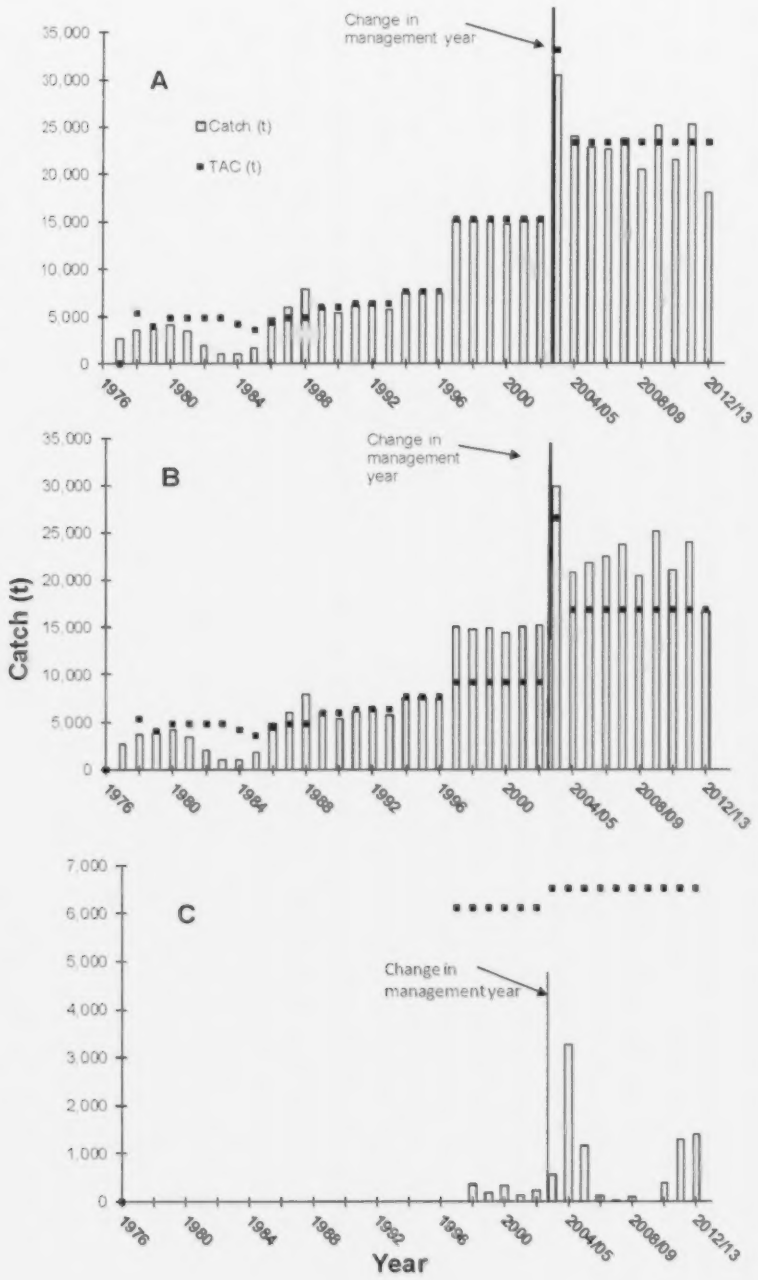


Figure 36 Historical Northern Shrimp catches (SFA 5) and TACs for the period 1976-2012-13 (data were up to January 28, 2013). In 2003, the management year changed to a fiscal year. A = total catch; B = large vessel catch; C = small vessel catch

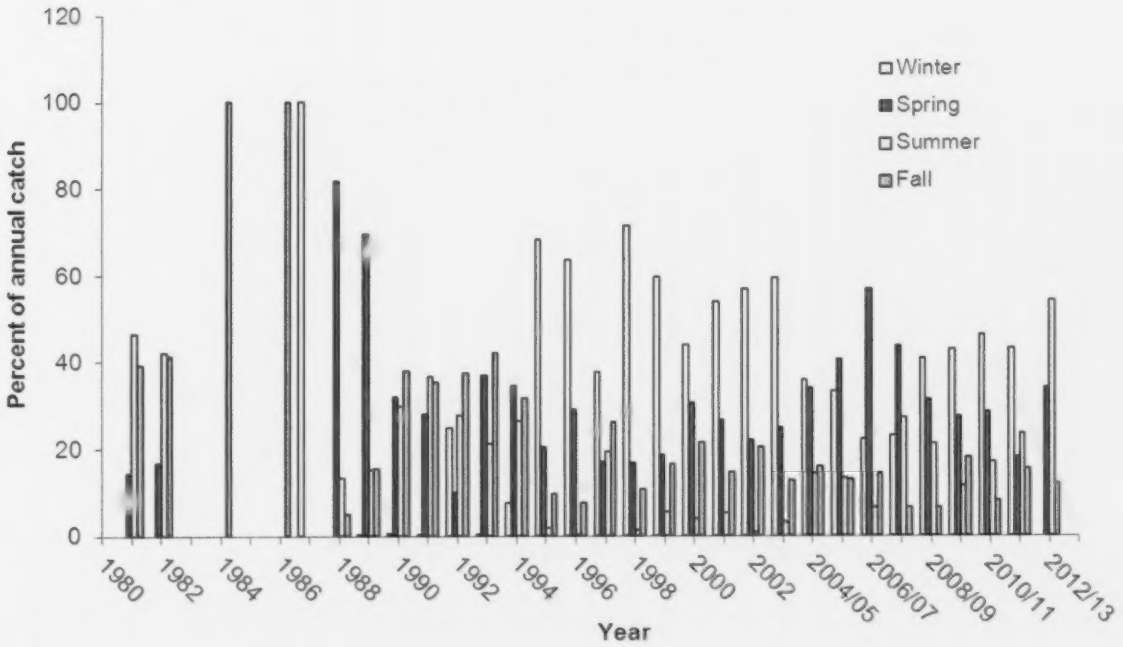


Figure 37 Seasonality of the large vessel (>500 t) shrimp fishery in Hopedale and Cartwright Channels (SFA 5) as determined from percent annual catch by season and year. After 2002, data were converted to management year values

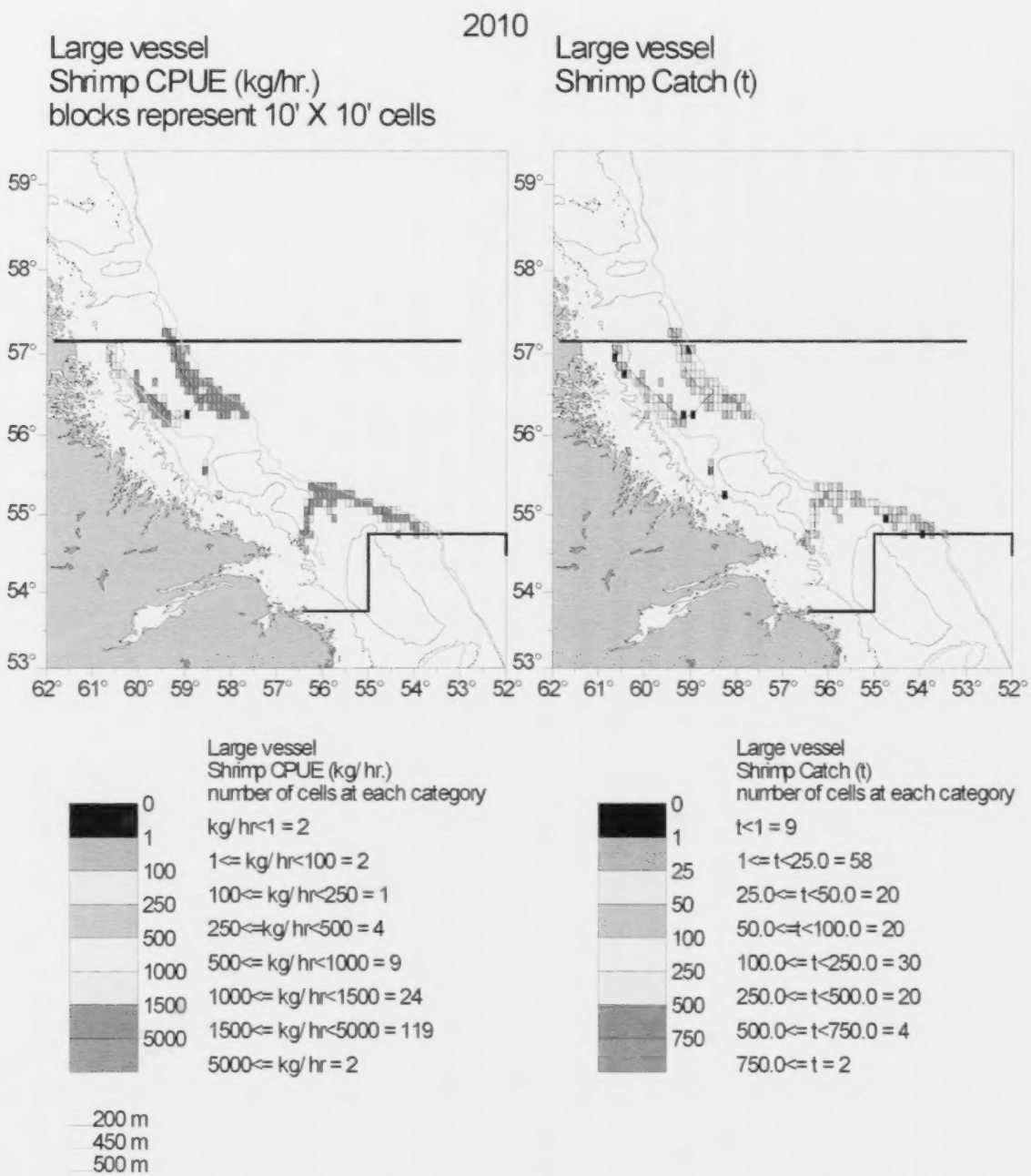


Figure 38 Large vessel (>500 t) catch and average fishery performance within the 2010-11 SFA 5 Northern Shrimp fishery

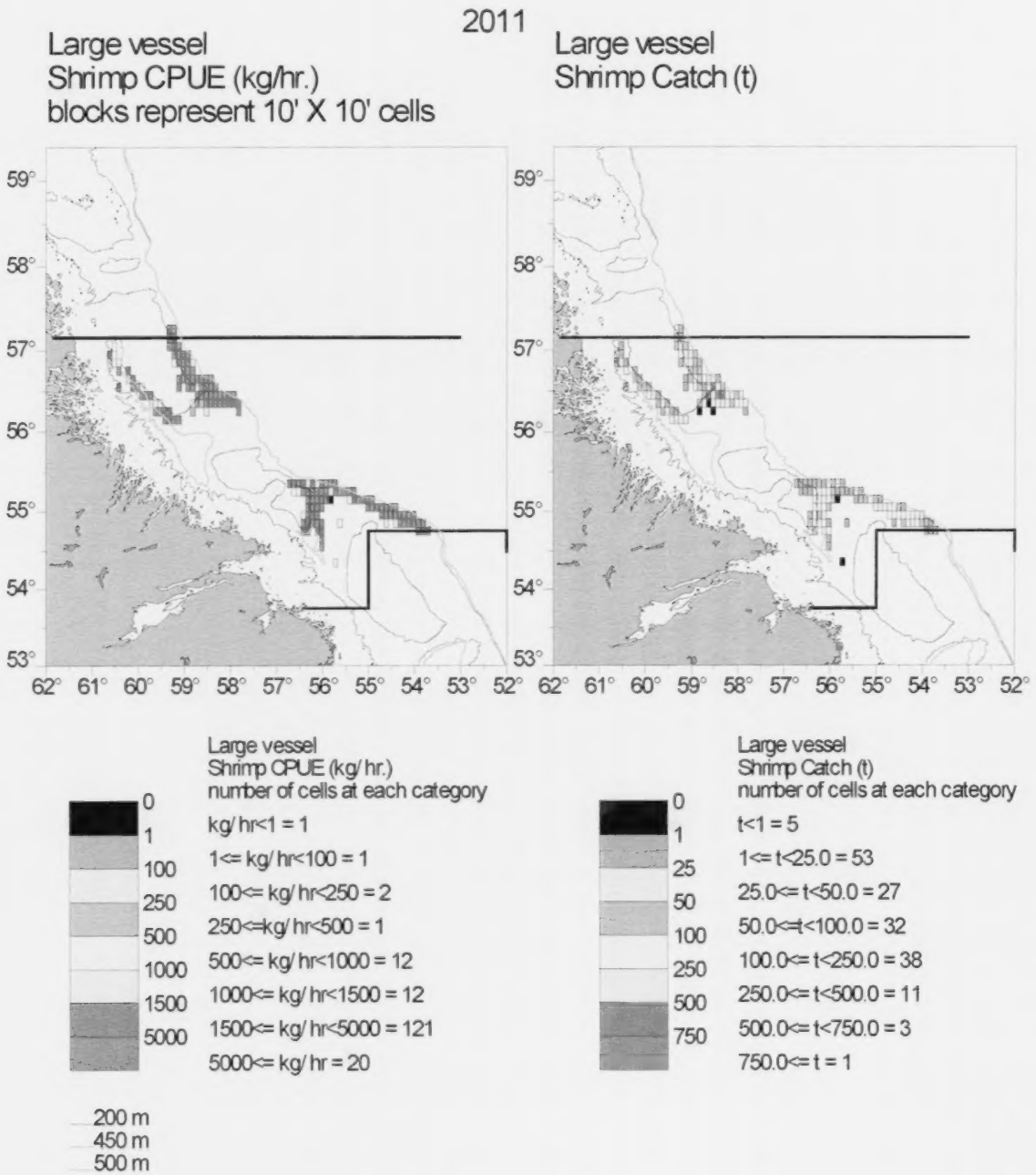


Figure 39 Large vessel (>500 t) catch and average fishery performance within the 2011-12 SFA 5 Northern Shrimp fishery

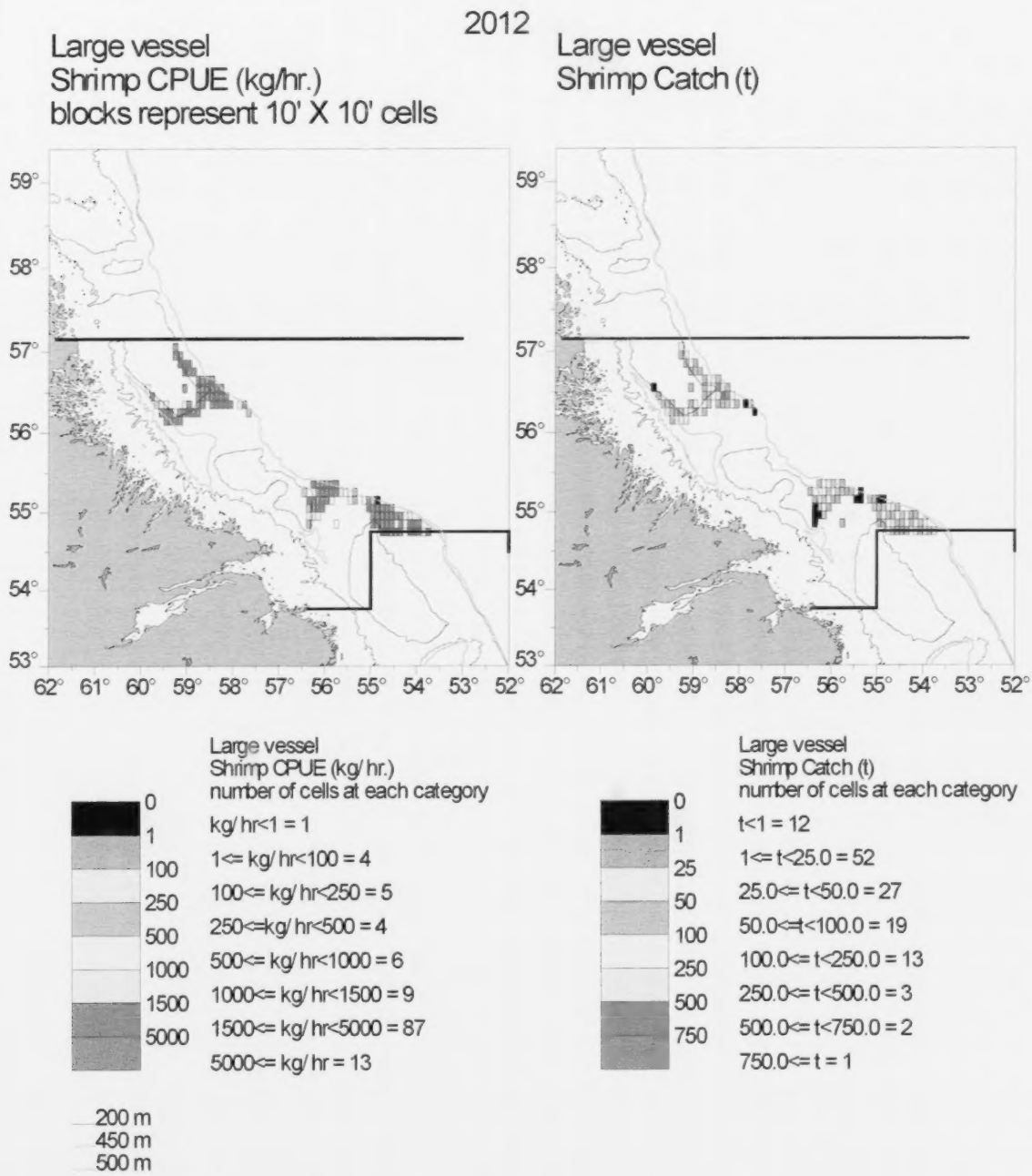


Figure 40 Large vessel (>500 t) catch and average fishery performance within the 2012-13 SFA 5 Northern Shrimp fishery. (Data were up to January 28, 2013

The GLM Procedure

Class Level Information

Class	Levels	Values
year	29	1980 1981 1982 1984 1985 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012
month	12	1 2 3 4 5 7 8 9 10 11 12 13 Standardized to June values
CFV	23	
area	4	51 52 53 54
gear	2	2 10

Number of Observations Read 2095
Number of Observations Used 2095

Dependent Variable: lncpue
Weight: effort

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	65	47671.58131	733.40894	106.23	<.0001
Error	2029	14007.75416	6.90377		
Corrected Total	2094	61679.33547			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.772894	34.98567	2.627503	7.510226

Source	DF	Type I SS	Mean Square	F Value	Pr > F
year	28	35878.88435	1281.38873	185.61	<.0001
month	11	4628.20745	420.74613	60.94	<.0001
CFV	22	5296.99916	240.77269	34.88	<.0001
Area	3	1399.65942	466.55314	67.58	<.0001
gear	1	467.83094	467.83094	67.76	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	28	6647.991187	237.428257	34.39	<.0001
month	11	4304.939215	391.358110	56.69	<.0001
CFV	22	4267.049437	193.956793	28.09	<.0001
area	3	1430.521634	476.840545	69.07	<.0001
gear	1	467.830940	467.830940	67.76	<.0001

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Intercept		7.629334330 B	0.05396986	141.36	<.0001
year	1980	-0.799833971 B	0.09213474	-8.68	<.0001
year	1981	-0.704079766 B	0.10495111	-6.71	<.0001
year	1982	-0.835653226 B	0.11969853	-6.98	<.0001
year	1984	-0.992602516 B	0.14784487	-6.71	<.0001
year	1985	-1.224466571 B	0.12274235	-9.98	<.0001
year	1989	-0.547321797 B	0.16323531	-3.35	0.0008
year	1990	-0.659328310 B	0.10074010	-6.54	<.0001
year	1991	-0.901902663 B	0.07888806	-11.43	<.0001
year	1992	-1.035034999 B	0.08220867	-12.59	<.0001

Figure 41 Original multiplicative year, month, vessel, area and gear CPUE model for large vessels (>500 t) fishing for shrimp in Hopedale and Cartwright Channels (SFA 5), 1980–2012-13, weighted by effort (Observer data, single + double trawl, no windows, history > 3 years)

Parameter		Estimate		Standard Error	t Value	Pr > |t|
year	1993	-0.957495264	B	0.06218038	-15.40	<.0001
year	1994	-0.791001212	B	0.05189280	-15.24	<.0001
year	1995	-0.481584196	B	0.05511293	-8.74	<.0001
year	1996	-0.244718673	B	0.06181539	-3.96	<.0001
year	1997	-0.189371853	B	0.04976739	-3.81	0.0001
year	1998	-0.136634121	B	0.05331586	-2.56	0.0105
year	1999	-0.118382368	B	0.05226883	-2.26	0.0236
year	2000	-0.022540277	B	0.05185689	-0.43	0.6639
year	2001	0.041830621	B	0.05262305	0.79	0.4268
year	2002	0.017034196	B	0.05433452	0.31	0.7539
year	2003	-0.011248086	B	0.05096708	-0.22	0.8254
year	2004	-0.095049353	B	0.04536757	-2.10	0.0363
year	2005	-0.085125744	B	0.04814811	-1.77	0.0772
year	2006	-0.043812683	B	0.04567344	-0.96	0.3375
year	2007	-0.033817834	B	0.04519928	-0.75	0.4544
year	2008	-0.149215773	B	0.04756452	-3.14	0.0017
year	2009	-0.105668653	B	0.04429476	-2.39	0.0171
year	2010	-0.045696350	B	0.04598049	-0.99	0.3204
year	2011	-0.097337084	B	0.04461762	-2.18	0.0293
year	2012	0.000000000	B	.	.	.
month	1	0.367244469	B	0.03232925	11.36	<.0001
month	2	0.602239343	B	0.03715177	16.21	<.0001
month	3	0.434271270	B	0.03859356	11.25	<.0001
month	4	0.282365153	B	0.03521994	8.02	<.0001
month	5	0.083329489	B	0.03259295	2.56	0.0106
month	7	0.093023662	B	0.03854569	2.41	0.0159
month	8	0.096146895	B	0.04161275	2.31	0.0210
month	9	-0.169930371	B	0.03795759	-4.48	<.0001
month	10	-0.102353747	B	0.03841974	-2.66	0.0078
month	11	-0.008502564	B	0.04341399	-0.20	0.8447
month	12	0.053047201	B	0.03593439	1.48	0.1400
month	13	0.000000000	B	.	.	.
CFV		0.214368586	B	0.05442523	3.94	<.0001
CFV		0.149954204	B	0.03510509	4.27	<.0001
CFV		0.037165082	B	0.03501520	1.06	0.2886
CFV		0.184597022	B	0.04646063	3.97	<.0001
CFV		0.108474834	B	0.07037261	1.54	0.1234
CFV		0.014968847	B	0.04318583	0.35	0.7289
CFV		-0.043470803	B	0.05328322	-0.82	0.4147
CFV		0.244716439	B	0.03381455	7.24	<.0001
CFV		-0.132787309	B	0.06334395	-2.10	0.0362
CFV		0.082649027	B	0.04111671	2.01	0.0446
CFV		0.126380708	B	0.05275727	2.40	0.0167
CFV		0.211158694	B	0.04554140	4.64	<.0001
CFV		0.064973616	B	0.04934874	1.32	0.1881
CFV		0.308857030	B	0.05826406	5.30	<.0001
CFV		-0.400368390	B	0.05377361	-7.45	<.0001
CFV		0.409732185	B	0.04704319	8.71	<.0001
CFV		0.301416600	B	0.05391189	5.59	<.0001
CFV		0.370411189	B	0.04490029	8.25	<.0001

Figure 41 (Cont'd)

Parameter		Estimate		Standard Error	t Value	Pr > |t|
CFV		-0.266786028	B	0.04084895	-6.53	<.0001
CFV		-0.267849704	B	0.04112675	-6.51	<.0001
CFV		-0.432496142	B	0.05040920	-8.58	<.0001
CFV		-0.280191388	B	0.05377966	-5.21	<.0001
CFV		0.000000000	B	.	.	.
starea	51	-0.116624931	B	0.02295833	-5.08	<.0001
starea	52	0.213182255	B	0.02112795	10.09	<.0001
starea	53	-0.031094341	B	0.09407378	-0.33	0.7410
starea	54	0.000000000	B	.	.	.
gear	2	-0.198528581	B	0.02411692	-8.23	<.0001
gear	10	0.000000000	B	.	.	.

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

year	lncpue LSMEAN	95 % Confidence Limits	
1980	6.934576	6.771195	7.097956
1981	7.030330	6.835710	7.224949
1982	6.898756	6.673587	7.123926
1984	6.741807	6.459295	7.024319
1985	6.509943	6.277768	6.742117
1989	7.187088	6.873239	7.500937
1990	7.075081	6.886476	7.263687
1991	6.832507	6.691244	6.973770
1992	6.699375	6.552504	6.846245
1993	6.776914	6.673637	6.880192
1994	6.943408	6.863775	7.023042
1995	7.252825	7.160373	7.345278
1996	7.489691	7.383107	7.596275
1997	7.545038	7.463891	7.626184
1998	7.597775	7.509787	7.685763
1999	7.616027	7.530990	7.701064
2000	7.711869	7.625173	7.798566
2001	7.776240	7.688059	7.864422
2002	7.751444	7.658880	7.844008
2003	7.723161	7.636490	7.809832
2004	7.639360	7.565766	7.712954
2005	7.649284	7.568513	7.730055
2006	7.690597	7.615954	7.765240
2007	7.700592	7.624966	7.776218
2008	7.585194	7.501869	7.668518
2009	7.628741	7.551601	7.705881
2010	7.688713	7.608716	7.768711
2011	7.637072	7.559573	7.714572
2012	7.734410	7.648971	7.819848

Figure 41. (Cont'd)

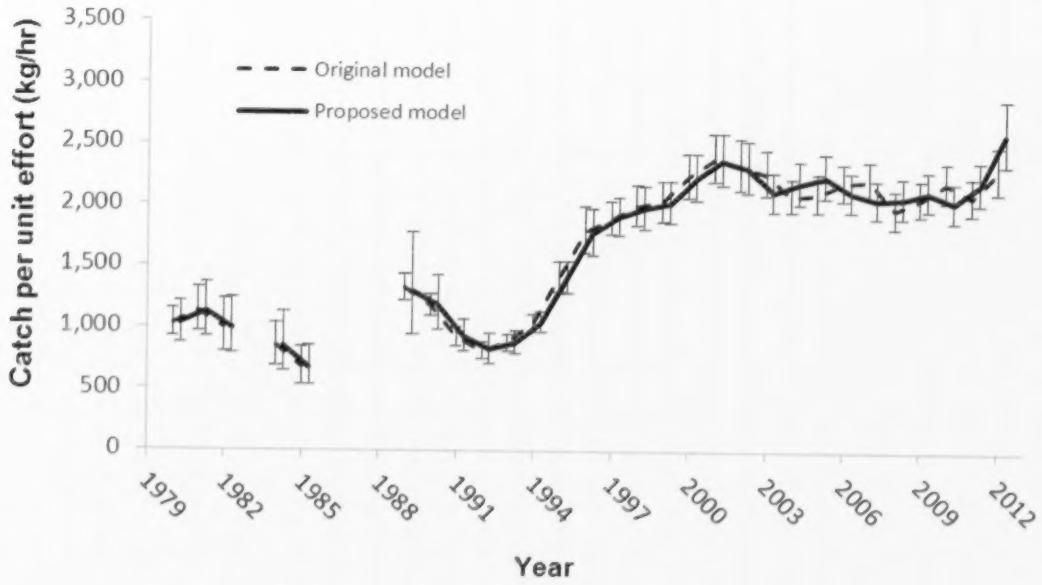


Figure 42 Overlay of original and proposed SFA 5 large vessel (>500 t) CPUE model (error bars indicate 95 % confidence intervals

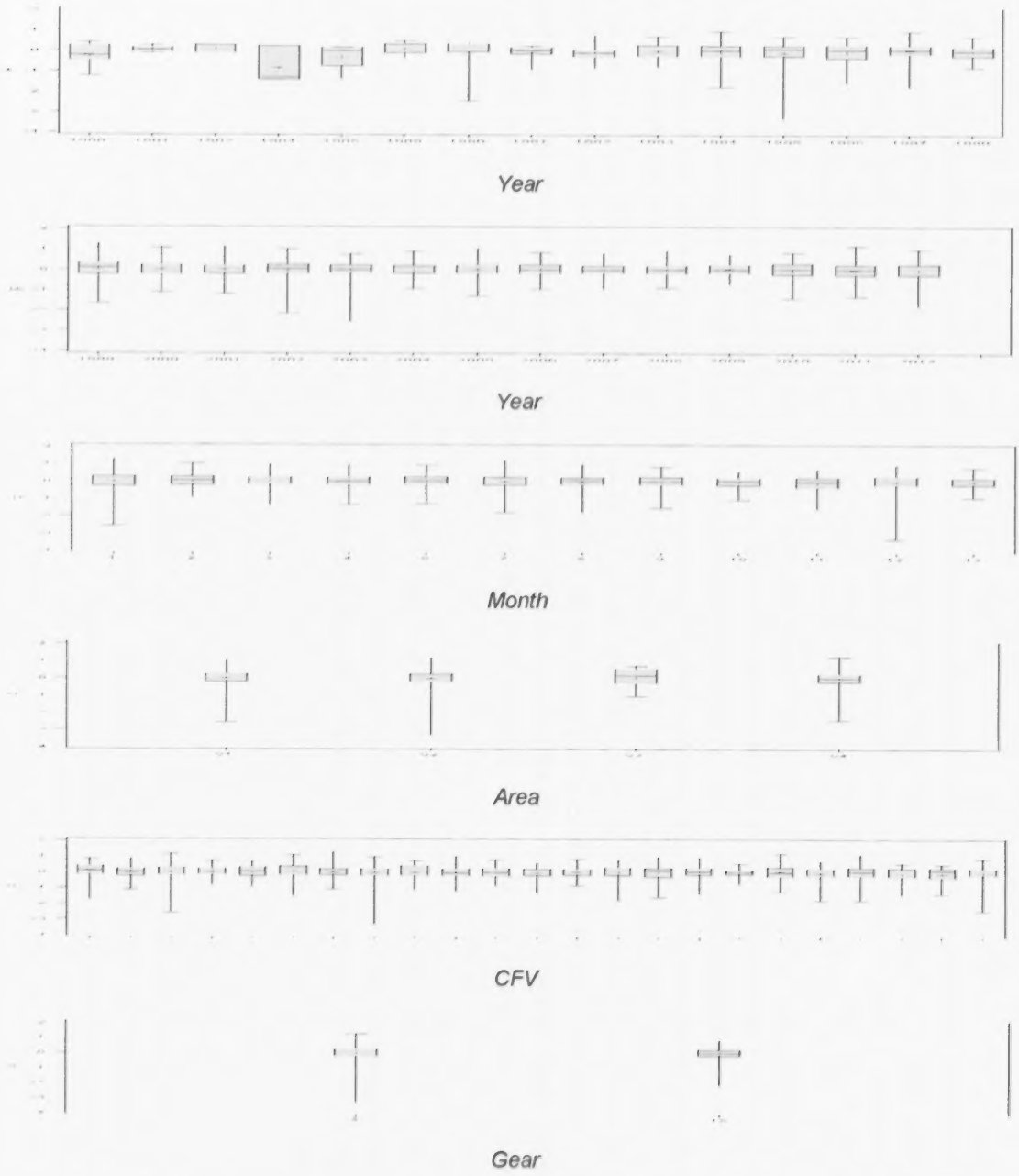


*Figure 43 Residuals around the **original** fishery performance model parameters for large vessels (>500 t) fishing shrimp in SFA 5 over the period 1980-2012*

The GLM Procedure

Class Level Information

Class	Levels	Values
year	29	1981 1982 1984 1985 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2020 Standardized to 1980 values
month	12	1 2 3 4 5 7 8 9 10 11 12 13 Standardized to June values
CFV	23	
area	4	51 52 53 54
gear	2	2 10 (Single trawl = 2; Double trawl = 10)

Number of Observations Read 2072
Number of Observations Used 2072

Dependent Variable: lncpue
Weight: effort

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	65	47781.18100	735.09509	107.21	<.0001
Error	2006	13754.27326	6.85657		
Corrected Total	2071	61535.45426			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.776482	34.86306	2.618505	7.510829

Source	DF	Type I SS	Mean Square	F Value	Pr > F
year	28	35702.11837	1275.07566	185.96	<.0001
month	11	4864.84351	442.25850	64.50	<.0001
CFV	22	5311.97397	241.45336	35.21	<.0001
area	3	1434.89821	478.29940	69.76	<.0001
gear	1	467.34694	467.34694	68.16	<.0001
Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	28	6710.194199	239.649793	34.95	<.0001
month	11	4420.314099	401.846736	58.61	<.0001
CFV	22	4269.016220	194.046192	28.30	<.0001
Area	3	1459.931640	486.643880	70.97	<.0001
gear	1	467.346936	467.346936	68.16	<.0001

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Intercept		6.824645905 B	0.09313773	73.27	<.0001
year	1981	0.088533482 B	0.10989856	0.81	0.4206
year	1982	-0.037522745 B	0.12395484	-0.30	0.7621
year	1984	-0.192150874 B	0.15130417	-1.27	0.2042
year	1985	-0.421620262 B	0.14056543	-3.00	0.0027
year	1989	0.229864206 B	0.17802854	1.29	0.1968
year	1990	0.140394822 B	0.11505771	1.22	0.2225
year	1991	-0.105164188 B	0.10172270	-1.03	0.3013
year	1992	-0.228208310 B	0.10762059	-2.12	0.0341
year	1993	-0.159112432 B	0.09251504	-1.72	0.0856

Figure 44 Proposed multiplicative year, month, vessel, area and gear CPUE model for large vessels (>500 t) fishing for shrimp in Hopedale and Cartwright Channels (SFA 5), 1980 – 2012/13, weighted by effort (Observer data, single + double trawl, no windows, history > 3 years). Data after 2002 were changed to management year; the model was standardized to 1980 values

Parameter		Estimate		Standard Error	t Value	Pr > |t|
year	1994	0.007888142	B	0.08596006	0.09	0.9269
year	1995	0.308611806	B	0.09178242	3.36	0.0008
year	1996	0.541865376	B	0.09464230	5.73	<.0001
year	1997	0.611528586	B	0.08660431	7.06	<.0001
year	1998	0.651472954	B	0.09073278	7.18	<.0001
year	1999	0.673506140	B	0.08972305	7.51	<.0001
year	2000	0.769280924	B	0.08834116	8.71	<.0001
year	2001	0.832619905	B	0.08804657	9.46	<.0001
year	2002	0.806001358	B	0.09146573	8.81	<.0001
year	2003	0.714669107	B	0.08844555	8.08	<.0001
year	2004	0.748379629	B	0.08983143	8.33	<.0001
year	2005	0.773642623	B	0.09000732	8.60	<.0001
year	2006	0.715110103	B	0.08924662	8.01	<.0001
year	2007	0.686629889	B	0.08983771	7.64	<.0001
year	2008	0.692005659	B	0.09086334	7.62	<.0001
year	2009	0.718006734	B	0.08993639	7.98	<.0001
year	2010	0.674206073	B	0.09030127	7.47	<.0001
year	2011	0.747692817	B	0.09103286	8.21	<.0001
year	2012	0.919206387	B	0.09594030	9.58	<.0001
year	2020	0.000000000	B	.	.	.
month	1	0.381294242	B	0.03249385	11.73	<.0001
month	2	0.616914629	B	0.03705760	16.65	<.0001
month	3	0.453223241	B	0.03844495	11.79	<.0001
month	4	0.286946410	B	0.03509369	8.18	<.0001
month	5	0.103535830	B	0.03250223	3.19	0.0015
month	7	0.076905500	B	0.03848002	2.00	0.0458
month	8	0.080862104	B	0.04147422	1.95	0.0514
month	9	-0.179474309	B	0.03783011	-4.74	<.0001
month	10	-0.113786031	B	0.03827567	-2.97	0.0030
month	11	-0.006497180	B	0.04320412	-0.15	0.8805
month	12	0.056917452	B	0.03573266	1.59	0.1113
month	13	0.000000000	B	.	.	.
CFV		0.213899241	B	0.05423059	3.94	<.0001
CFV		0.160909664	B	0.03500713	4.60	<.0001
CFV		0.039852065	B	0.03488365	1.14	0.2534
CFV		0.177353115	B	0.04614679	3.84	0.0001
CFV		0.110676585	B	0.07020199	1.58	0.1151
CFV		0.013127036	B	0.04304621	0.30	0.7604
CFV		-0.041003355	B	0.05310365	-0.77	0.4401
CFV		0.243390209	B	0.03363568	7.24	<.0001
CFV		-0.129094175	B	0.06312118	-2.05	0.0410
CFV		0.078146367	B	0.04095522	1.91	0.0565
CFV		0.134726297	B	0.05256735	2.56	0.0105
CFV		0.211954572	B	0.04550167	4.66	<.0001
CFV		0.079383740	B	0.04960154	1.60	0.1097
CFV		0.290243608	B	0.05828070	4.98	<.0001
CFV		-0.396692573	B	0.05359070	-7.40	<.0001
CFV		0.418302540	B	0.04657240	8.98	<.0001
CFV		0.311334057	B	0.05357436	5.81	<.0001
CFV		0.372120548	B	0.04475945	8.31	<.0001

Figure 44 (Cont'd.)

Parameter		Estimate	Standard Error	t Value	Pr > |t|
CFV		-0.265262188 B	0.04074209	-6.51	<.0001
CFV		-0.271029927 B	0.04097646	-6.61	<.0001
CFV		-0.423948031 B	0.05027333	-8.43	<.0001
CFV		-0.271257550 B	0.05363182	-5.06	<.0001
CFV		0.000000000 B	.	.	.
starea	51	-0.111246861 B	0.02290907	-4.86	<.0001
starea	52	0.220406721 B	0.02119477	10.40	<.0001
starea	53	-0.028223487 B	0.09375660	-0.30	0.7634
starea	54	0.000000000 B	.	.	.
gear	2	-0.198303300 B	0.02401948	-8.26	<.0001
gear	10	0.000000000 B	.	.	.

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

year	lncpue LSMEAN	95 % Confidence Limits	
1981	7.026628	6.832673	7.220582
1982	6.900571	6.676188	7.124955
1984	6.745943	6.464418	7.027468
1985	6.516474	6.285084	6.747864
1989	7.167958	6.855133	7.480784
1990	7.078489	6.890537	7.266441
1991	6.832930	6.692153	6.973707
1992	6.709886	6.563481	6.856291
1993	6.778982	6.676135	6.881829
1994	6.945982	6.866681	7.025283
1995	7.246706	7.154466	7.338946
1996	7.479959	7.373567	7.586352
1997	7.549623	7.468755	7.630490
1998	7.589567	7.501741	7.677393
1999	7.611600	7.526783	7.696417
2000	7.707375	7.620909	7.793841
2001	7.770714	7.682768	7.858660
2002	7.744095	7.651762	7.836428
2003	7.652763	7.578523	7.727004
2004	7.686474	7.606810	7.766137
2005	7.711737	7.631893	7.791580
2006	7.653204	7.577869	7.728539
2007	7.624724	7.548672	7.700776
2008	7.630100	7.550474	7.709726
2009	7.656101	7.580159	7.732043
2010	7.612300	7.534545	7.690056
2011	7.685787	7.605095	7.766478
2012	7.857300	7.755075	7.959526
2020	6.938094	6.775262	7.100926

Figure 44 (Cont'd.)

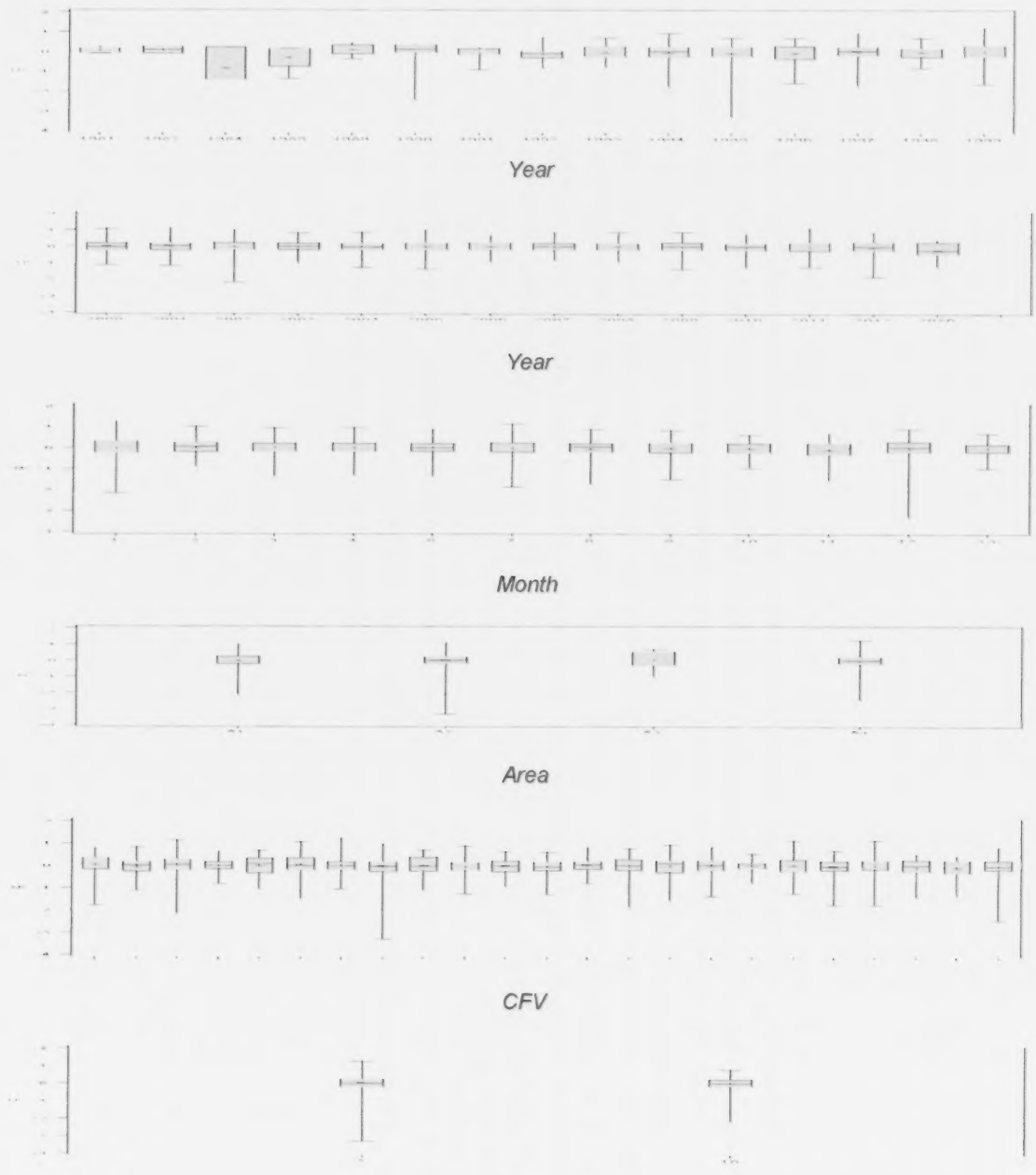


Figure 45 Residuals around the proposed fishery performance model parameters for large vessels (>500 t) fishing shrimp in SFA 5 over the period 1980-2012

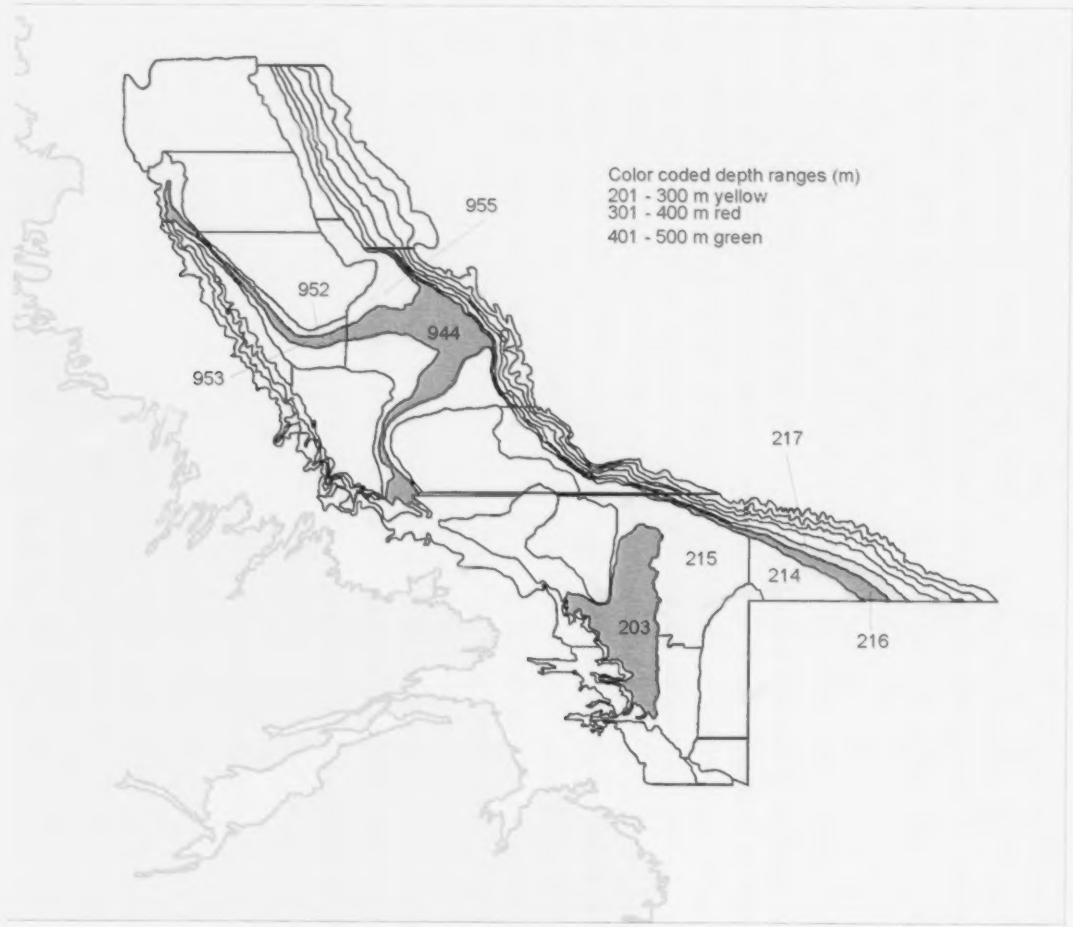


Figure 46 Index strata within SFA 5 that were consistently fished by the large vessel fleet over the period 1994-2012. The numbers indicate the strata within Tables 27 and 29

Figure 47 Observed northern shrimp length frequencies (per 000) from the Canadian large vessel (>500 t) fleet fishing shrimp in Hopedale and Cartwright Channels (SFA 5) over the period 2003-12. Solid lines = males; dotted lines = females. These length frequencies are based upon management year data

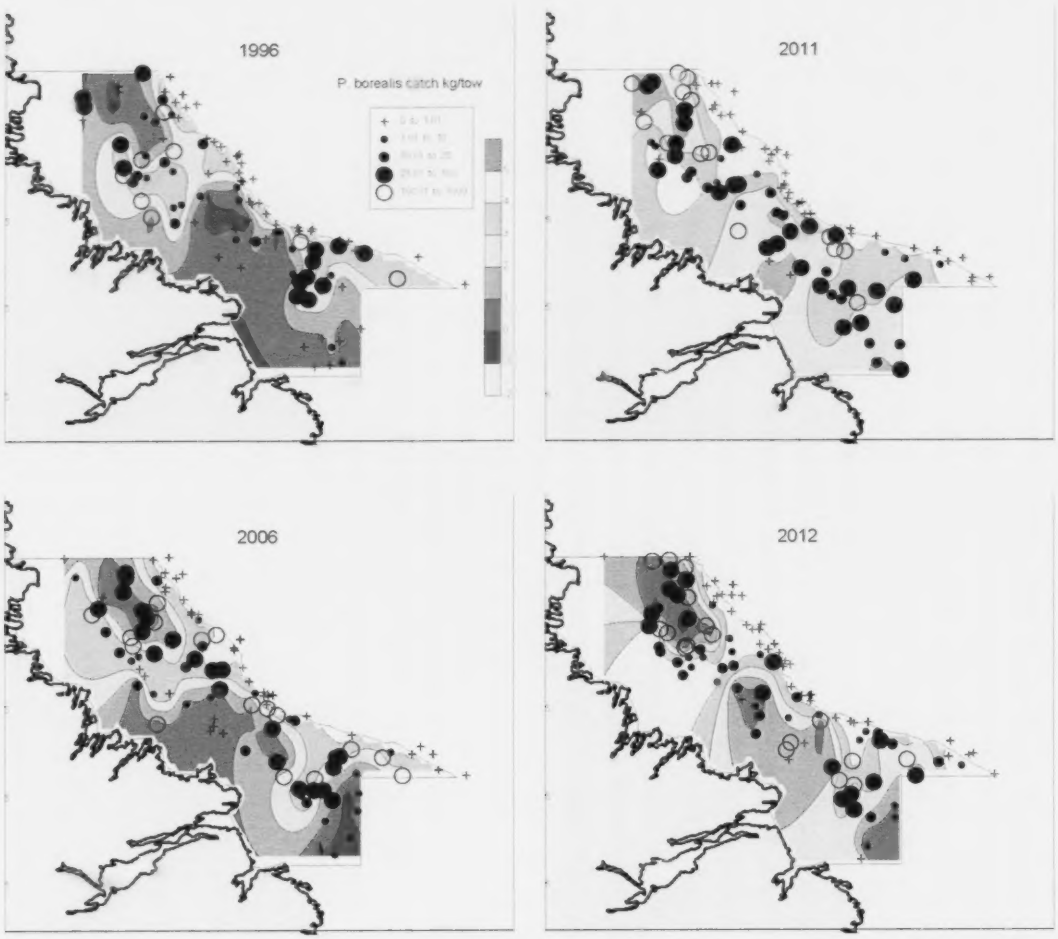


Figure 48 Overlay of SFA 5 Northern Shrimp (Pandalus borealis) catches (kg/tow) upon bottom temperatures as obtained from the autumn research bottom trawl surveys conducted over the period 1996-2012

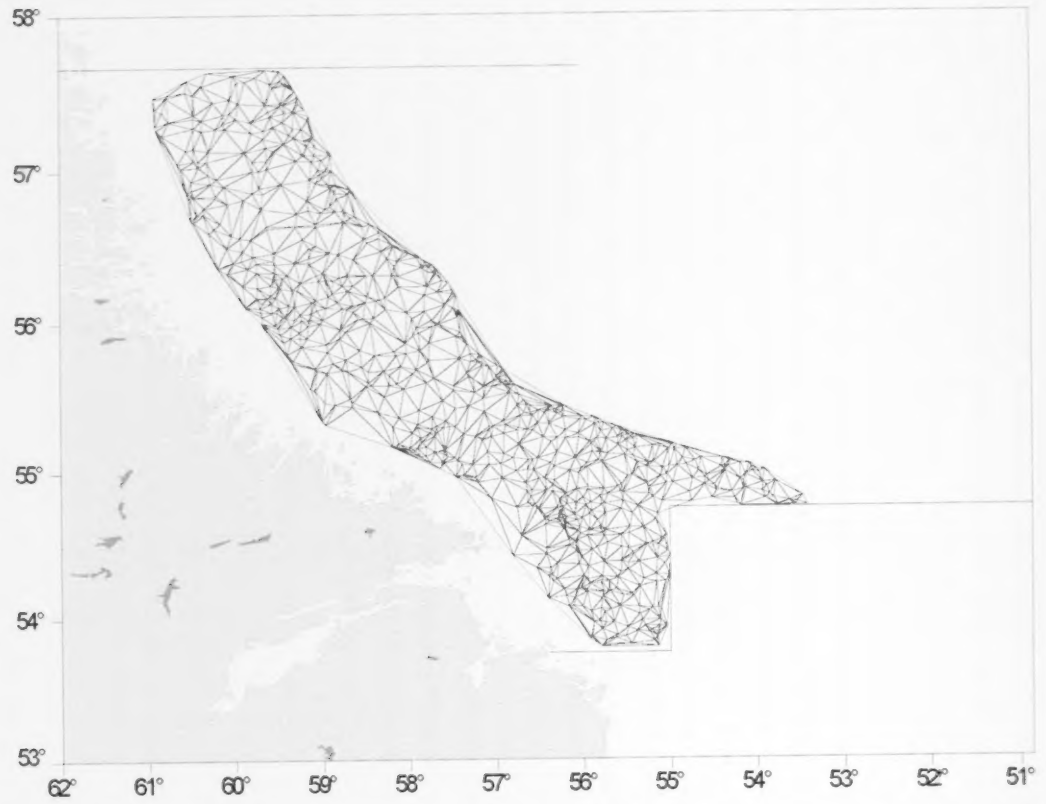


Figure 49 SFA 5 Delauney triangulations used in the Ogive Mapping calculations of survey indices

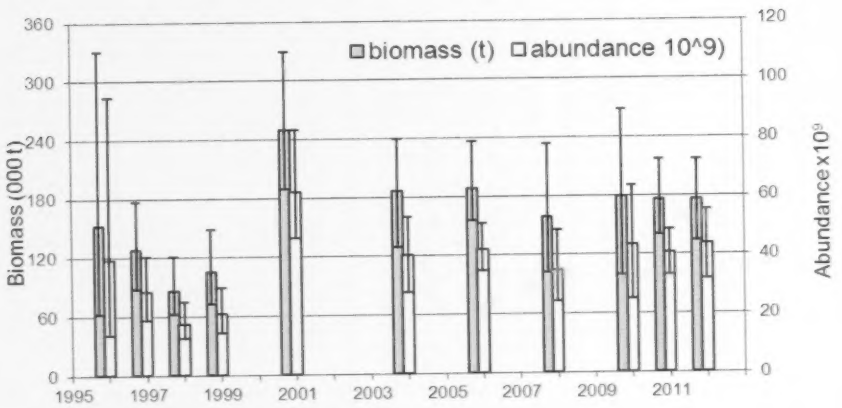


Figure 50 Autumn Northern Shrimp (Pandalus borealis) biomass and abundance indices within Hopedale and Cartwright Channels (SFA 5), as determined using Ogive Mapping calculations

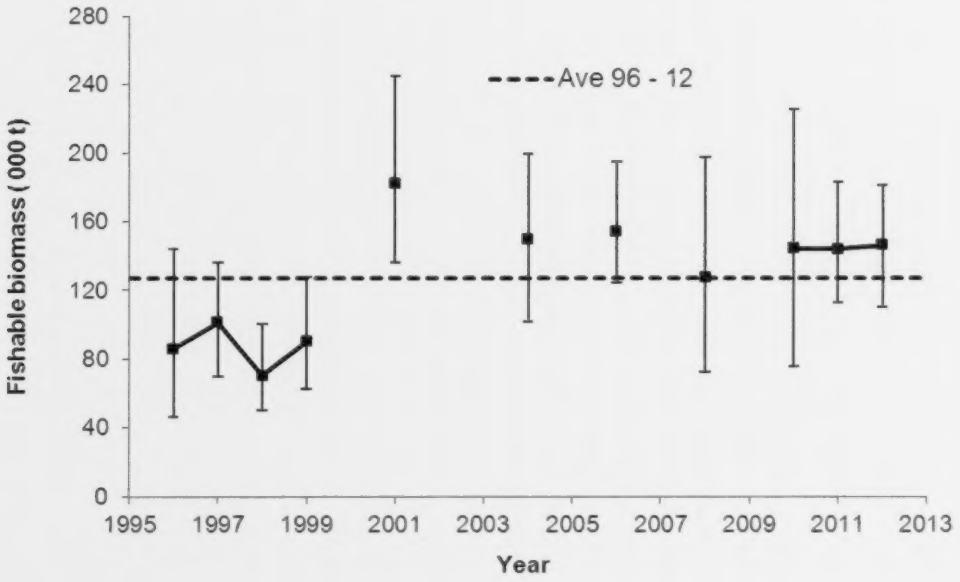


Figure 51 Fishable biomass index with the entire of SFA 5 (error bars indicate 95 % confidence intervals)

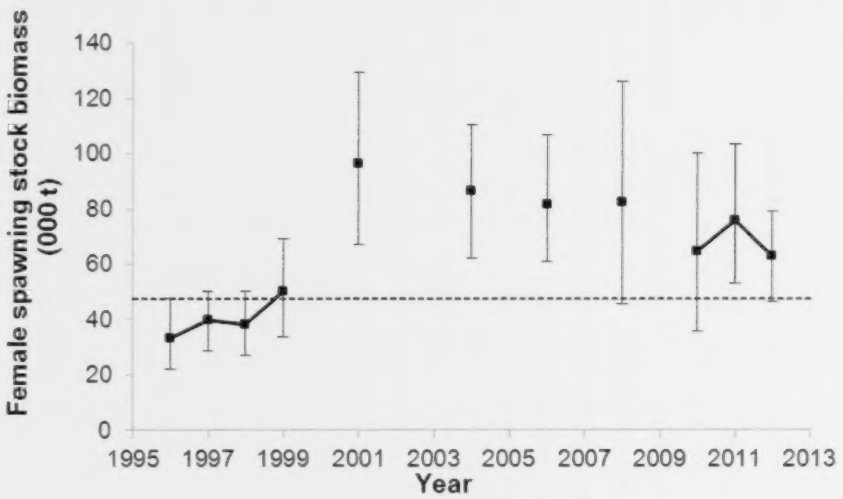
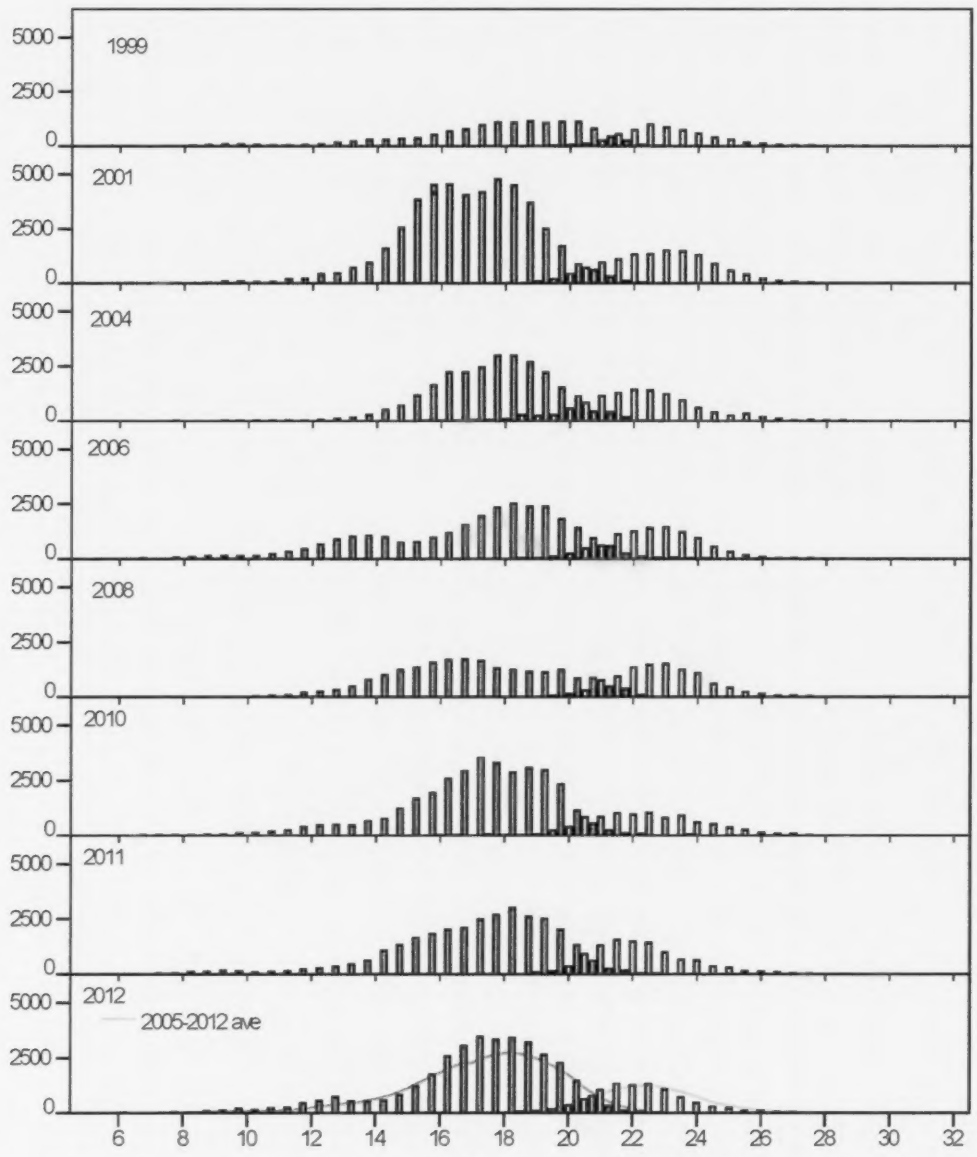


Figure 52. SFA 5 SSB index (error bars indicate 95 % confidence intervals). The dotted line is the geometric mean over the years 1996-2001 and is used as a proxy for B_{MSY}.



Pandalus borealis length frequency histograms (abundance 10^6), 1999-2012; carapace length (mm)
(line represents the long term mean; male shrimp are red while female shrimp are green).

Figure 53 Abundance at length for Hopedale and Cartwright Channels (SFA 5) Northern Shrimp as estimated by Ogive Mapping calculations of NSRF – DFO joint shrimp survey data, 1999-2012

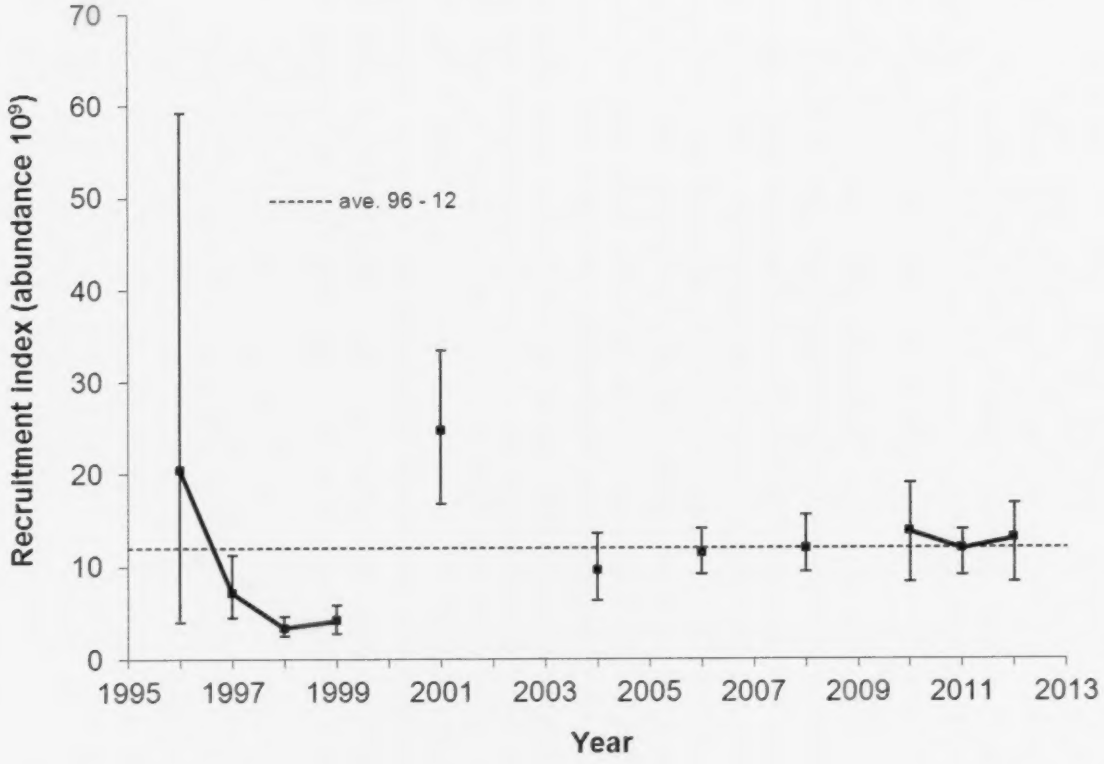


Figure 54 SFA 5 Northern Shrimp recruitment indices defined as abundances of 11.5-17 mm carapace lf animals of both sexes

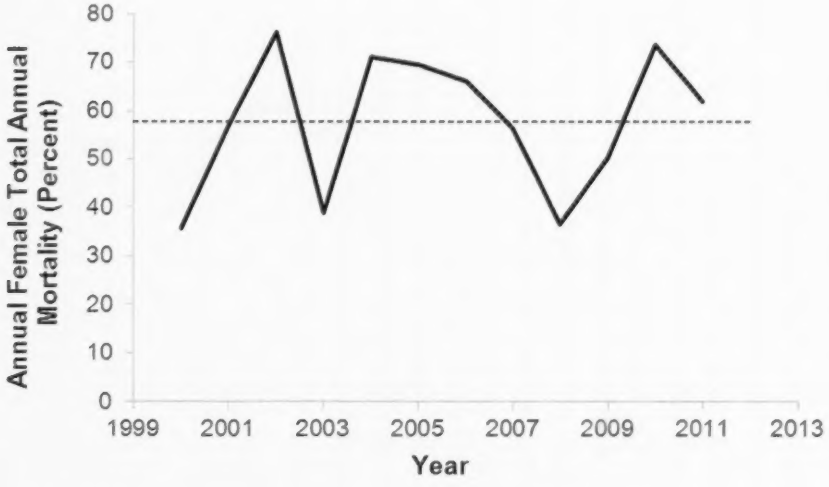


Figure 55 SFA 5 total annual mortality as determined from survival of females (primiparous + multiparous) to the next year as multiparous animals, averaged over four years. Year is the third year of the four year period. The dotted line is the average over the time series

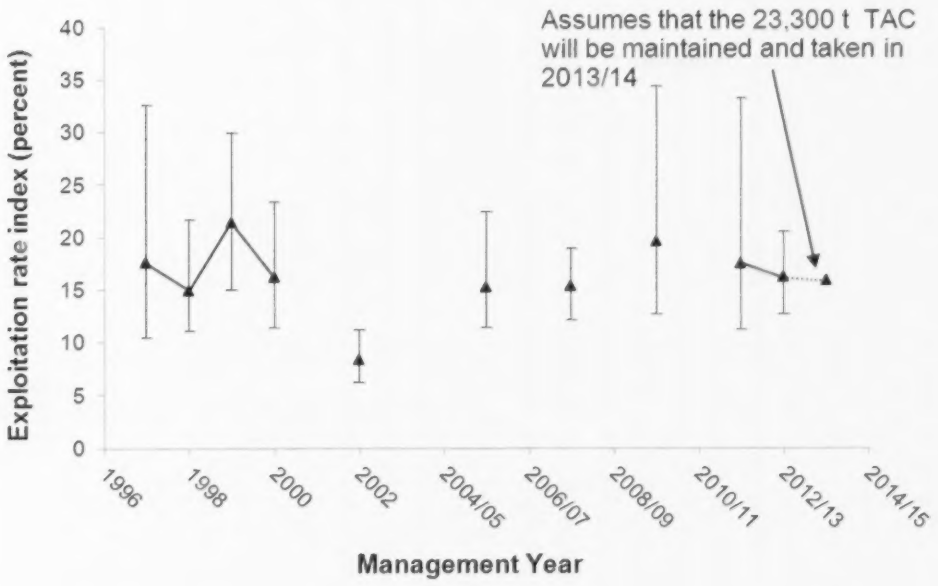


Figure 56. SFA 5 exploitation rate index based on the total catch/fishable biomass index from the previous year, expressed as a percentage. Error bars indicate 95 % confidence intervals. The 2012-13 fishery was ongoing therefore the catch was set equal to the TAC.

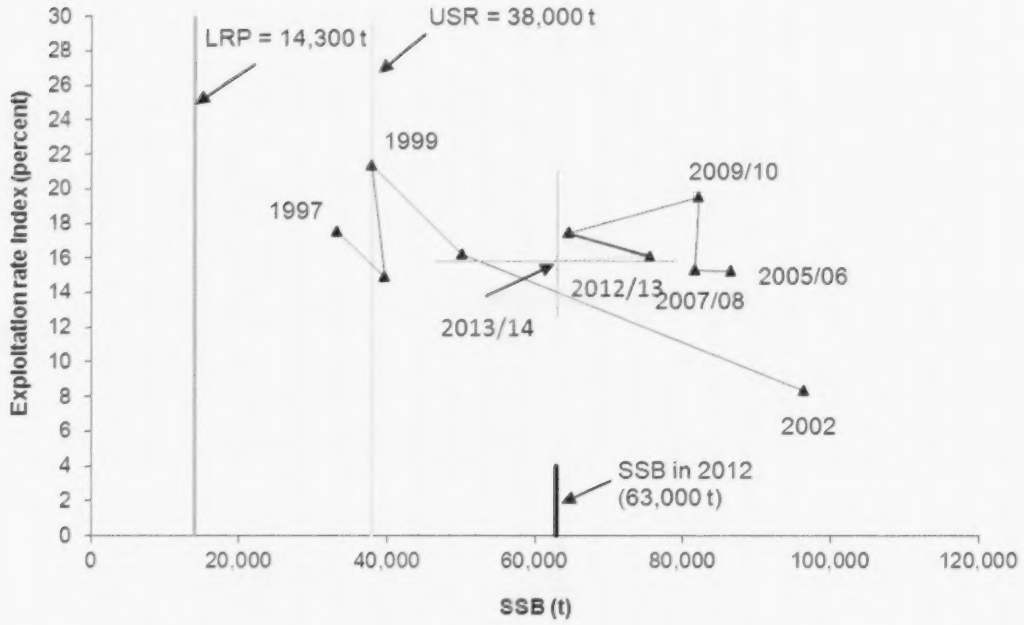


Figure 57 SFA 5 Precautionary Approach framework with trajectory of exploitation rate index vs SSB. Numbers denote management year. The red cross indicates the 95 % confidence interval for the autumn 2012 SSB (horizontal bar), and the exploitation rate if the 2012-13 TAC of 23,300 t is maintained (vertical bar) through 2013-14

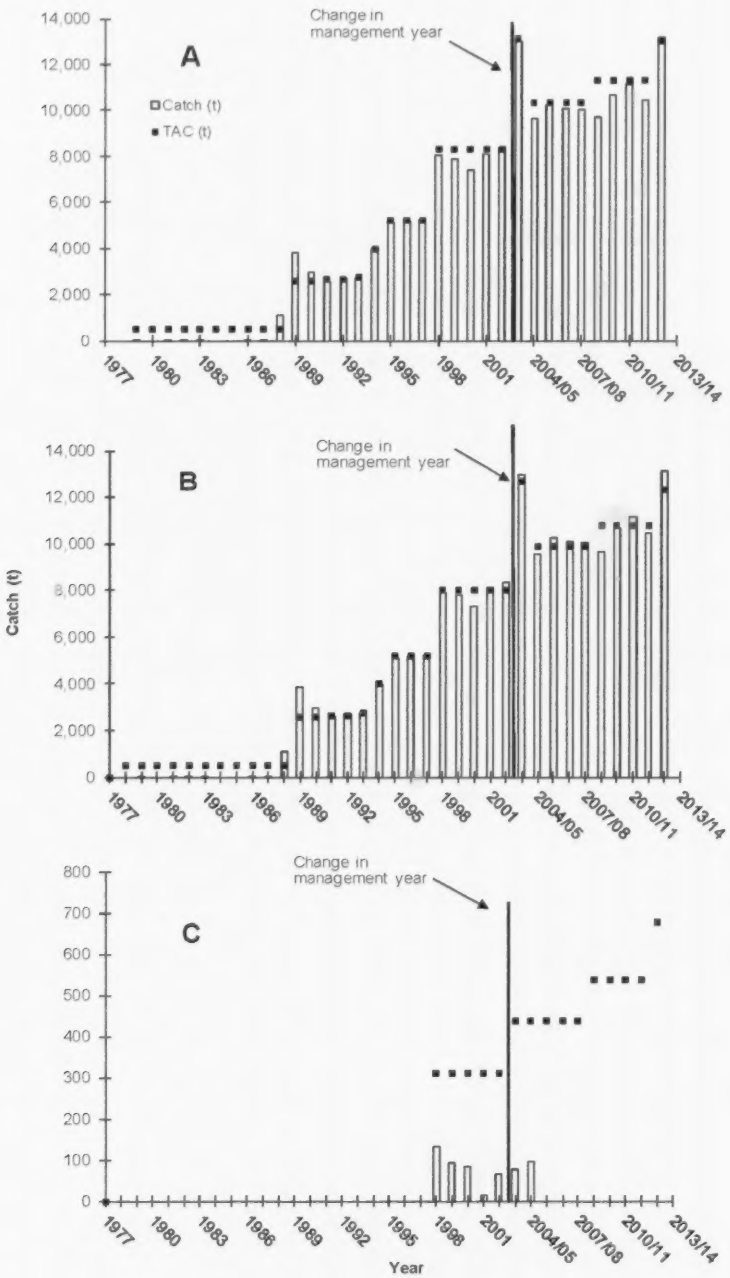


Figure 58 Historical Northern Shrimp catches (SFA 4) and TACs for the period 1977-2012-13 (2012-13 catches are up to January 28, 2013). In 2003, the management year changed to a fiscal year. A = total catch; B = large vessel catch; C = small vessel catch

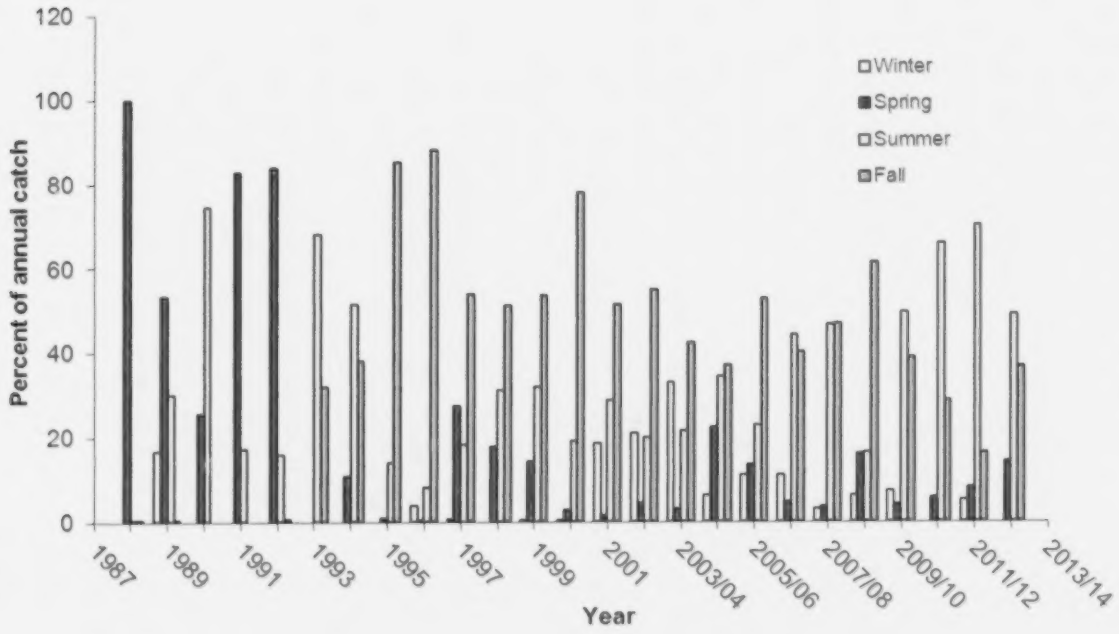


Figure 59 Seasonality of the large vessel fleet fishing shrimp in SFA 4

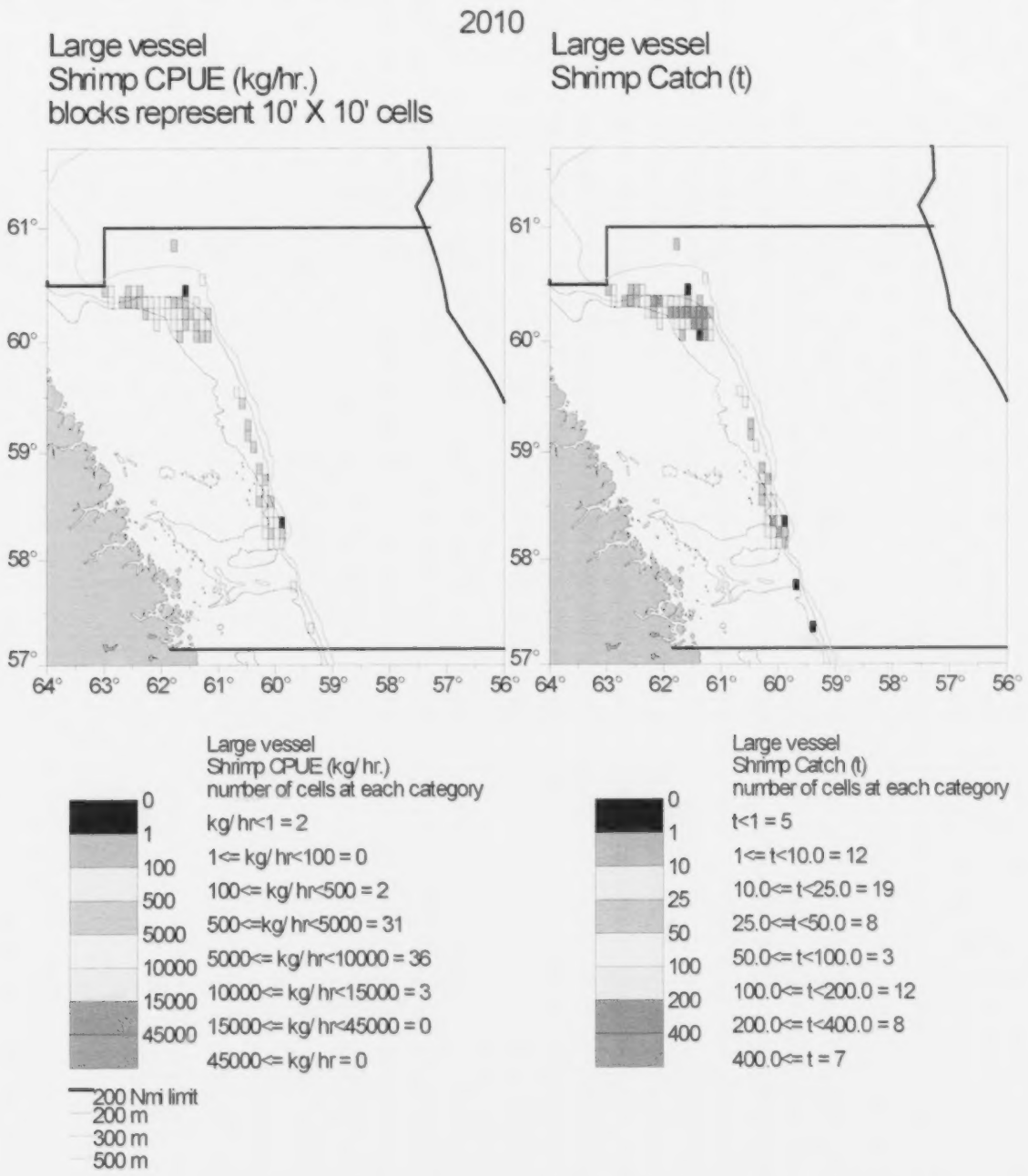


Figure 60 Large vessel (>500 t) catch and average fishery performance within the 2010-11 SFA 4 Northern Shrimp fishery

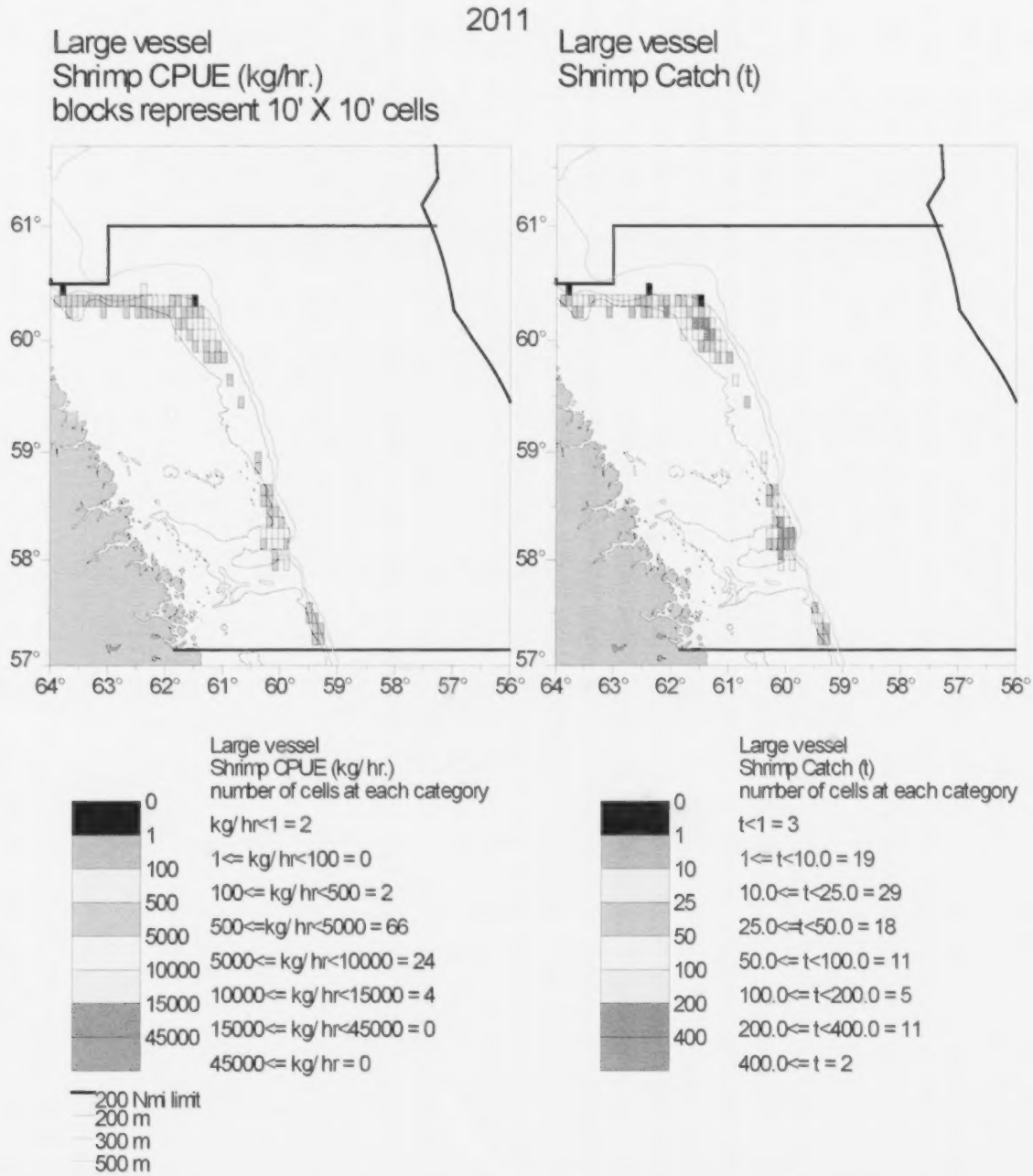


Figure 61 Large vessel (>500 t) catch and average fishery performance within the 2011-12 SFA 4 Northern Shrimp fishery

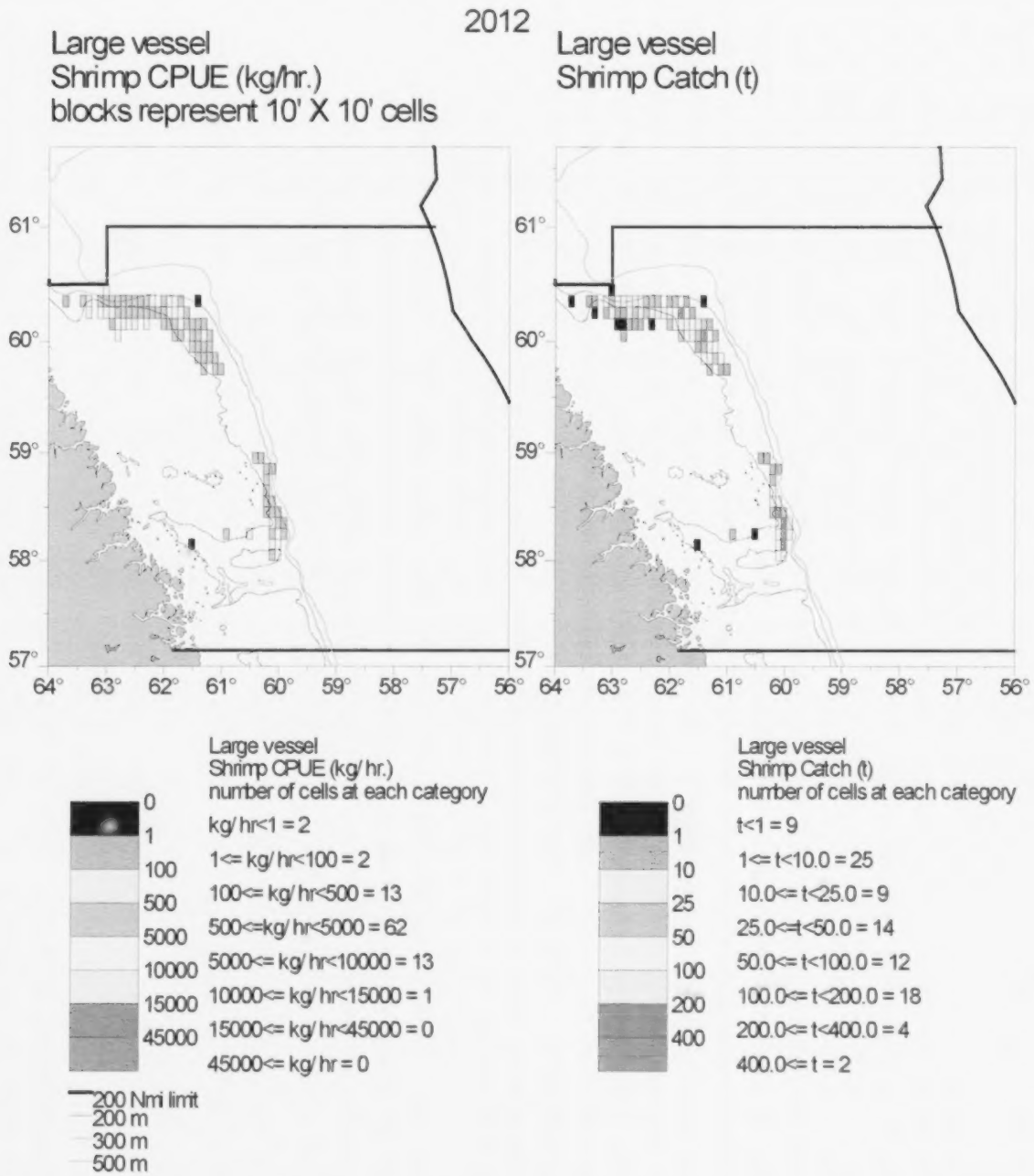


Figure 62 Large vessel (>500 t) catch and average fishery performance within the 2012-13 SFA 6 Northern Shrimp fishery. (Data were up to January 28, 2013)

The GLM Procedure

Class Level Information

Class	Levels	Values
year	24	1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012
month	11	1 2 4 5 6 8 9 10 11 12 99 Standardized to July
CFV	17	
Area	2	49 100 Standardized to the northern area 48

Number of Observations Read 701
Number of Observations Used 701

Dependent Variable: lncpue
Weight: effort

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	50	8937.87464	178.75749	20.78	<.0001
Error	650	5590.44393	8.60068		
Corrected Total	700	14528.31857			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.615204	37.76898	2.932692	7.764816

Source	DF	Type I SS	Mean Square	F Value	Pr > F
year	23	7200.496610	313.065070	36.40	<.0001
month	10	571.347401	57.134740	6.64	<.0001
CFV	16	1116.015925	69.750995	8.11	<.0001
Area	1	50.014700	50.014700	5.82	0.0162

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	23	4256.839097	185.079961	21.52	<.0001
month	10	430.577322	43.057732	5.01	<.0001
CFV	16	1108.843338	69.302709	8.06	<.0001
Area	1	50.014700	50.014700	5.82	0.0162

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		7.701745817	B	0.10407312	74.00	<.0001
year	1989	-0.899185342	B	0.19738966	-4.56	<.0001
year	1990	-1.358414941	B	0.12520814	-10.85	<.0001
year	1991	0.242032702	B	0.20283375	1.19	0.2332
year	1992	-0.299400178	B	0.14539774	-2.06	0.0399
year	1993	0.162944321	B	0.15323249	1.06	0.2880
year	1994	0.265316065	B	0.13727242	1.93	0.0537
year	1995	-0.708067192	B	0.10259907	-6.90	<.0001
year	1996	-0.600765500	B	0.10105068	-5.95	<.0001
year	1997	0.080356292	B	0.13014460	0.62	0.5372
year	1998	-0.180646074	B	0.09862699	-1.83	0.0675
year	1999	-0.151094141	B	0.10090814	-1.50	0.1348

Parameter		Estimate		Standard Error	t Value	Pr > |t|
year	2000	-0.035157749	B	0.10611543	-0.33	0.7405
year	2001	0.417059674	B	0.11658432	3.58	0.0004
year	2002	-0.093558549	B	0.10147212	-0.92	0.3569
year	2003	0.029301682	B	0.09989927	0.29	0.7694
year	2004	-0.292177136	B	0.09067768	-3.22	0.0013
year	2005	-0.316915662	B	0.08858559	-3.58	0.0004

Figure 63 Original multiplicative year, month, vessel and gear CPUE model for large vessels (>500 t) fishing for shrimp in NAFO Subdivision 2G (SFA 4), 1989-2012-13, weighted by effort (Single + double trawls, observer data, no windows, history > 3 yrs.)

year	2006	-0.176297043 B	0.09109209	-1.94	0.0534
year	2007	-0.049080909 B	0.08830544	-0.56	0.5785
year	2008	0.013334573 B	0.08791295	0.15	0.8795
year	2009	0.346048938 B	0.09868465	3.51	0.0005
year	2010	0.394867810 B	0.09581143	4.12	<.0001
year	2011	0.219707569 B	0.10372884	2.12	0.0345
year	2012	0.000000000 B	.	.	.
month	1	0.106222987 B	0.08257099	1.29	0.1987
month	2	0.275264520 B	0.23218328	1.19	0.2362
month	4	-0.466418428 B	0.19637699	-2.38	0.0178
month	5	0.072627106 B	0.09510818	0.76	0.4454
month	6	-0.092390708 B	0.07935788	-1.16	0.2448
month	8	-0.091894906 B	0.06436844	-1.43	0.1539
month	9	-0.173255061 B	0.07305858	-2.37	0.0180
month	10	-0.255961225 B	0.06004760	-4.26	<.0001
month	11	-0.084986524 B	0.05648656	-1.50	0.1329
month	12	0.036606113 B	0.06380409	0.57	0.5664
month	99	0.000000000 B	.	.	.
CFV		0.429243783 B	0.15583866	2.75	0.0060
CFV		0.506818996 B	0.09875506	5.13	<.0001
CFV		0.315504088 B	0.07561026	4.17	<.0001
CFV		0.320080536 B	0.09242652	3.46	0.0006
CFV		0.220487134 B	0.07013370	3.14	0.0017
CFV		0.247361740 B	0.09535930	2.59	0.0097
CFV		0.392814255 B	0.06692423	5.87	<.0001
CFV		0.242535518 B	0.10330860	2.35	0.0192
CFV		0.161251555 B	0.08687123	1.86	0.0639
CFV		0.261099462 B	0.08492223	3.07	0.0022
CFV		0.264157752 B	0.11481294	2.30	0.0217
CFV		-0.113253209 B	0.09630414	-1.18	0.2400
CFV		0.513958441 B	0.09151461	5.62	<.0001
CFV		0.341200414 B	0.09282262	3.68	0.0003
CFV		0.573996527 B	0.08609543	6.67	<.0001
CFV		-0.040114848 B	0.07779151	-0.52	0.6063
CFV		0.000000000 B	.	.	.
Area	49	0.093671968 B	0.03884430	2.41	0.0162
Area	100	0.000000000 B	.	.	.

Figure 63 (Cont'd.)

	lncpue		
year	LSMEAN	95 % Confidence Limits	
1989	7.060880	6.700845	7.420915
1990	6.601650	6.399408	6.803893
1991	8.202098	7.833734	8.570462
1992	7.660665	7.415531	7.905799
1993	8.123010	7.859340	8.386679
1994	8.225381	7.995594	8.455168
1995	7.251998	7.107632	7.396364
1996	7.359300	7.217813	7.500787
1997	8.040422	7.826849	8.253994
1998	7.779419	7.641806	7.917032
1999	7.808971	7.668680	7.949262
2000	7.924907	7.769273	8.080542
2001	8.377125	8.190440	8.563810
2002	7.866507	7.717800	8.015213
2003	7.989367	7.841980	8.136754
2004	7.667888	7.547143	7.788633
2005	7.643150	7.518021	7.768279
2006	7.783768	7.645394	7.922142
2007	7.910984	7.773779	8.048190
2008	7.973400	7.828353	8.118446
2009	8.306114	8.139088	8.473141
2010	8.354933	8.202725	8.507141
2011	8.179773	8.003828	8.355718
2012	7.960065	7.810416	8.109714

Figure 63 (Cont'd.)

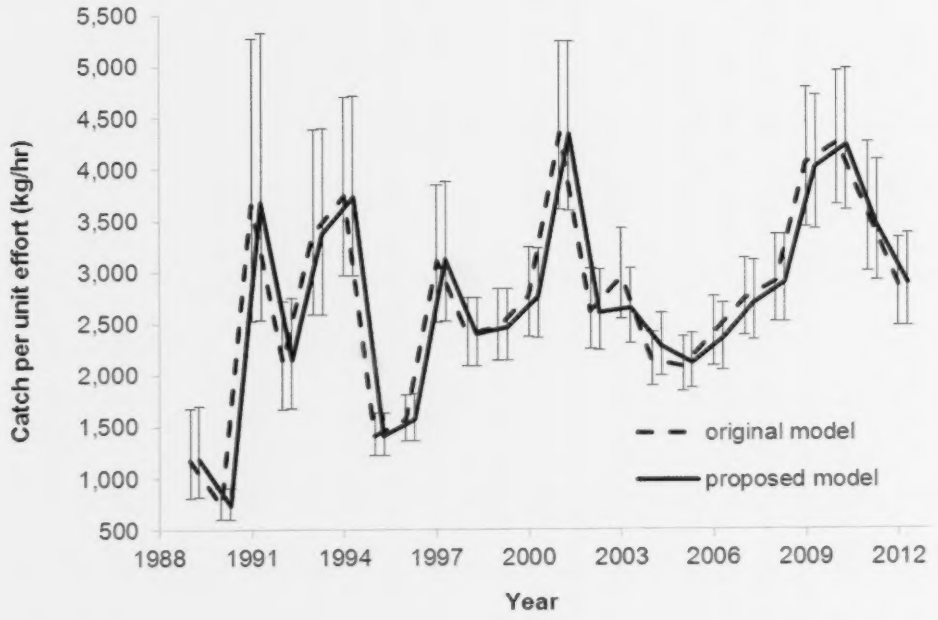


Figure 64 Overlay of original and proposed SFA 4 large vessel (>500 t) CPUE models (error bars indicate 95 % confidence intervals)

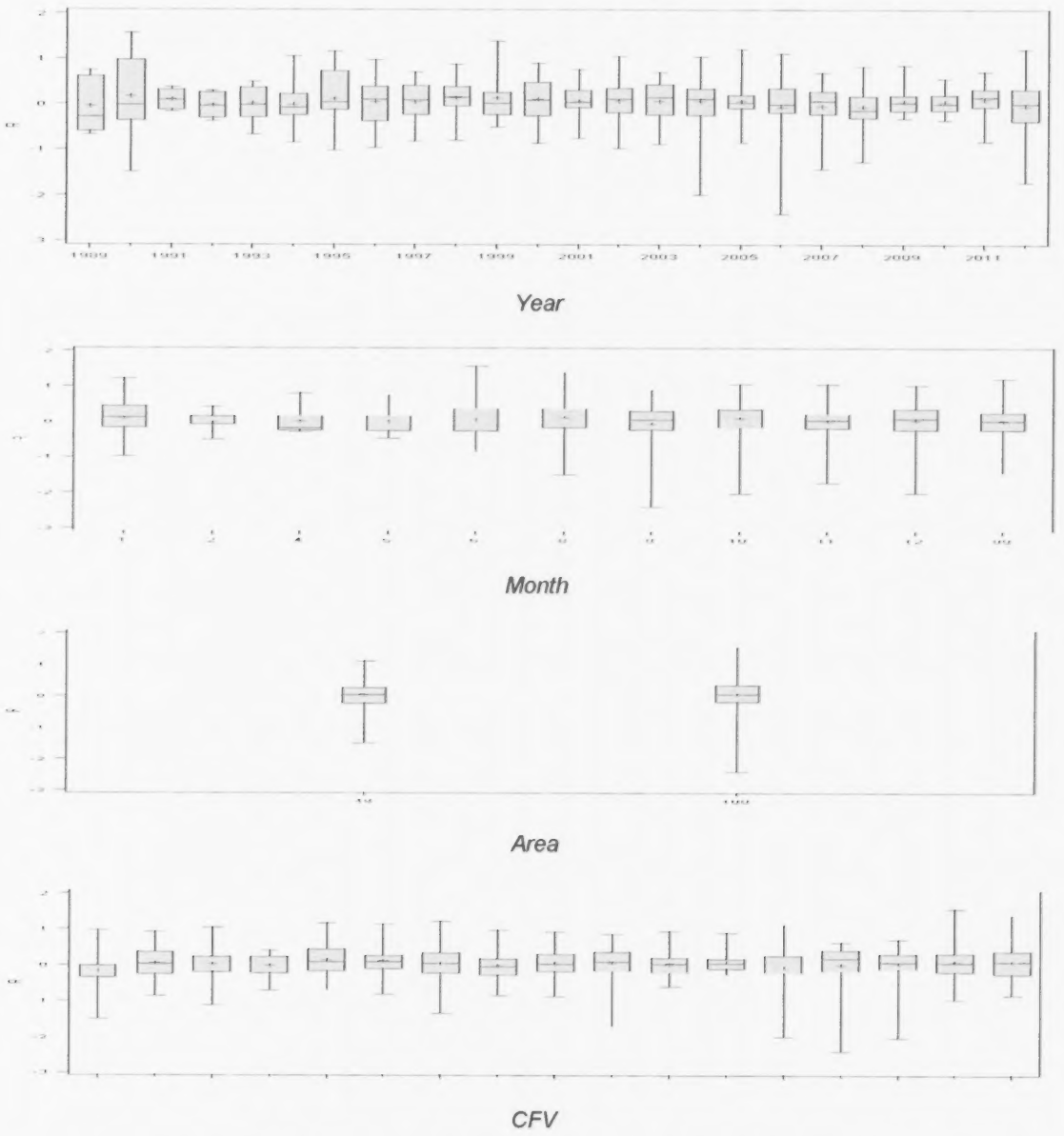


*Figure 65 Residuals around the **original** fishery performance model parameters for large vessels (>500 t) fishing shrimp in SFA 4 over the period 1989-2012*

The GLM Procedure

Class Level Information

Class	Levels	Values
year	24	1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2020 Standardized to 1989 values
month	11	1 2 4 5 6 7 8 9 10 12 99 Standardized to July values
CFV	17	
Area	2	49 100 Standardized to the northern area 48

Number of Observations Read 697
Number of Observations Used 697

Dependent Variable: lncpue
Weight: effort

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	50	8829.21457	176.58429	20.12	<.0001
Error	646	5670.59370	8.77801		
Corrected Total	696	14499.80827			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.608919	38.15191	2.962770	7.765719

Source	DF	Type I SS	Mean Square	F Value	Pr > F
year	23	7059.755779	306.945903	34.97	<.0001
month	10	575.913486	57.591349	6.56	<.0001
CFV	16	1140.990581	71.311911	8.12	<.0001
starea	1	52.554725	52.554725	5.99	0.0147

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	23	4119.735816	179.118949	20.41	<.0001
month	10	431.856384	43.185638	4.92	<.0001
CFV	16	1134.241743	70.890109	8.08	<.0001
starea	1	52.554725	52.554725	5.99	0.0147

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		6.735261038	B	0.19130783	35.21	<.0001
year	1990	-0.471787498	B	0.20451126	-2.31	0.0214
year	1991	1.136009669	B	0.24911238	4.56	<.0001
year	1992	0.597112109	B	0.21091670	2.83	0.0048
year	1993	1.050200390	B	0.22603179	4.65	<.0001
year	1994	1.152176925	B	0.21600258	5.33	<.0001
year	1995	0.177941899	B	0.19621867	0.91	0.3648
year	1996	0.286621159	B	0.19620860	1.46	0.1446
year	1997	0.973135664	B	0.20681302	4.71	<.0001
year	1998	0.707307997	B	0.19371802	3.65	0.0003
year	1999	0.735663323	B	0.19482613	3.78	0.0002
year	2000	0.848198373	B	0.19975915	4.25	<.0001

Figure 66 Proposed multiplicative year, month, vessel and area CPUE model for large vessels (>500 t) fishing for shrimp in NAFO Subdiv. 2G (SFA 4), 1989-2012-13, weighted by effort (Single + double trawl), observer data, no windows, history > 3 years). The model has been standardized to the first year and data were converted from calendar year to management year

Parameter		Estimate		Standard Error	t Value	Pr > |t|
year	2006	0.688333053	B	0.19776098	3.48	0.0005
year	2007	0.824373948	B	0.19949903	4.13	<.0001
year	2008	0.899230436	B	0.19909804	4.52	<.0001
year	2009	1.222990794	B	0.20479225	5.97	<.0001
year	2010	1.275397601	B	0.20307140	6.28	<.0001
year	2011	1.071355103	B	0.20593530	5.20	<.0001
year	2012	0.892047299	B	0.19966497	4.47	<.0001
year	2020	0.000000000	B	.	.	.
month	1	0.181774806	B	0.07995441	2.27	0.0233
month	2	0.373476798	B	0.23446391	1.59	0.1117
month	4	-0.429107719	B	0.19786753	-2.17	0.0305
month	5	0.133863978	B	0.09263591	1.45	0.1489
month	6	-0.014459692	B	0.07519803	-0.19	0.8476
month	7	0.083713550	B	0.05715461	1.46	0.1435
month	8	-0.004697969	B	0.05803968	-0.08	0.9355
month	9	-0.085321929	B	0.06861150	-1.24	0.2141
month	10	-0.175161602	B	0.04794569	-3.65	0.0003
month	12	0.130493451	B	0.05593779	2.33	0.0200
month	99	0.000000000	B	.	.	.
CFV		0.424764428	B	0.15743632	2.70	0.0072
CFV		0.502259345	B	0.09975208	5.04	<.0001
CFV		0.320304598	B	0.07638305	4.19	<.0001
CFV		0.321961815	B	0.09321594	3.45	0.0006
CFV		0.211938064	B	0.07080488	2.99	0.0029
CFV		0.241287163	B	0.09630607	2.51	0.0125
CFV		0.392789661	B	0.06755181	5.81	<.0001
CFV		0.240431185	B	0.10438937	2.30	0.0216
CFV		0.148413673	B	0.08738526	1.70	0.0899
CFV		0.268525382	B	0.08547435	3.14	0.0018
CFV		0.283338457	B	0.11607392	2.44	0.0149
CFV		-0.117952842	B	0.09726896	-1.21	0.2257
CFV		0.526357697	B	0.09230072	5.70	<.0001
CFV		0.334852381	B	0.09378322	3.57	0.0004
CFV		0.571390137	B	0.08686102	6.58	<.0001
CFV		-0.050406723	B	0.07861165	-0.64	0.5216
CFV		0.000000000	B	.	.	.
starea	49	0.096103133	B	0.03927622	2.45	0.0147
starea	100	0.000000000	B	.	.	.

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

Figure 66 (Cont'd.)

year	lnopue LSMEAN	95 % Confidence Limits	
1990	6.600993	6.396539	6.805448
1991	8.208790	7.836419	8.581162
1992	7.669893	7.422018	7.917768
1993	8.122981	7.956606	8.289357
1994	8.224958	7.992779	8.457137
1995	7.250723	7.104893	7.396553
1996	7.359402	7.216331	7.502473
1997	8.045916	7.829957	8.261876
1998	7.780089	7.640980	7.919198
1999	7.808444	7.666663	7.950225
2000	7.920979	7.763903	8.078055
2001	8.375177	8.186371	8.563984
2002	7.863002	7.712476	8.013528
2003	7.878408	7.741658	8.015158
2004	7.728981	7.597180	7.860782
2005	7.657011	7.531537	7.782484
2006	7.761114	7.624116	7.898112
2007	7.897155	7.754004	8.040306
2008	7.972011	7.825876	8.118147
2009	8.295772	8.134631	8.456912
2010	8.348178	8.185696	8.510661
2011	8.144136	7.974188	8.314084
2012	7.964828	7.809298	8.120358
2020	7.072781	6.708897	7.436665

Figure 66 (Cont'd.)

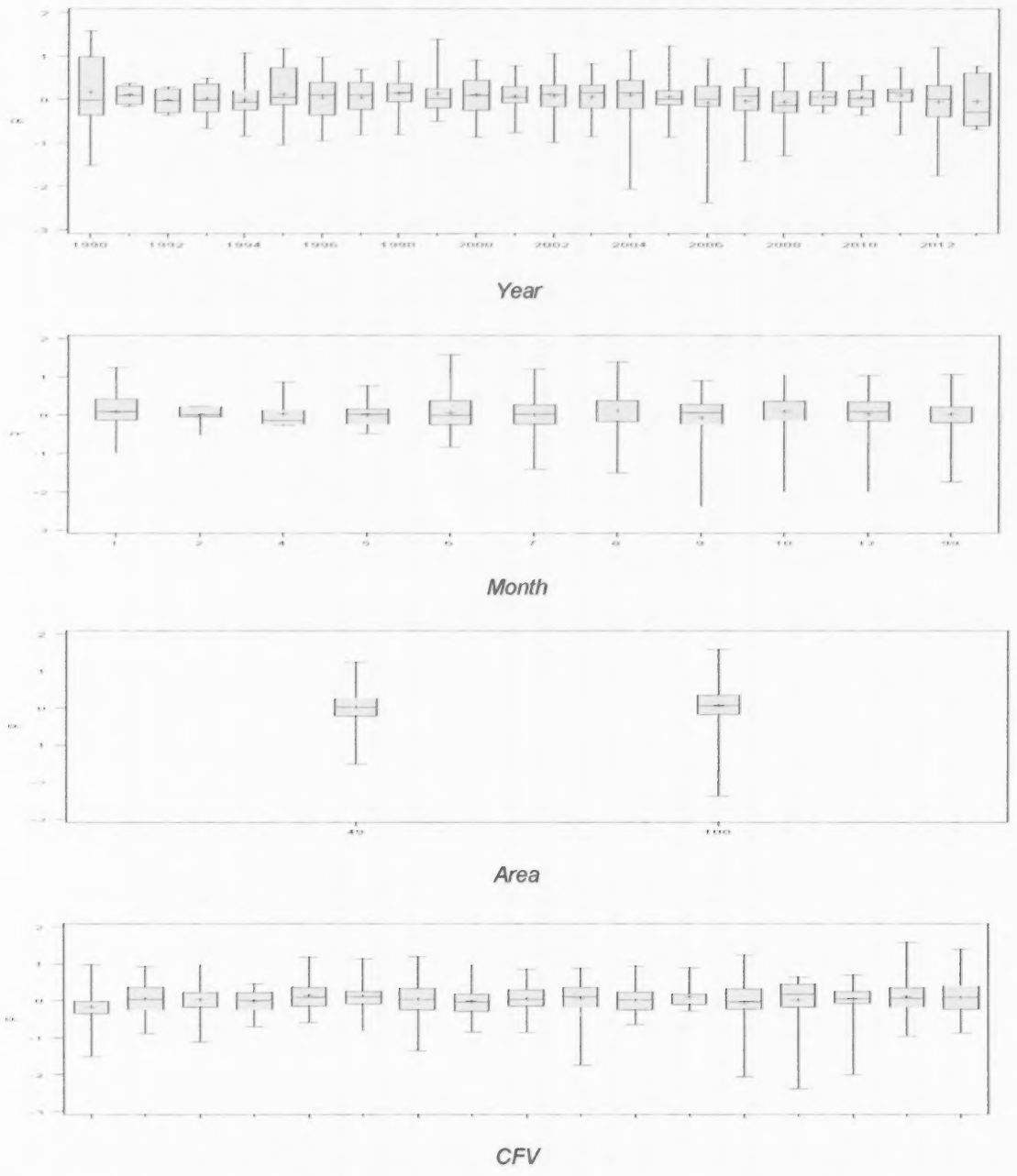


*Figure 67 Residuals around the **proposed** fishery performance model parameters for large vessels (>500 t) fishing shrimp in SFA 4 over the period 1989-2012-13*

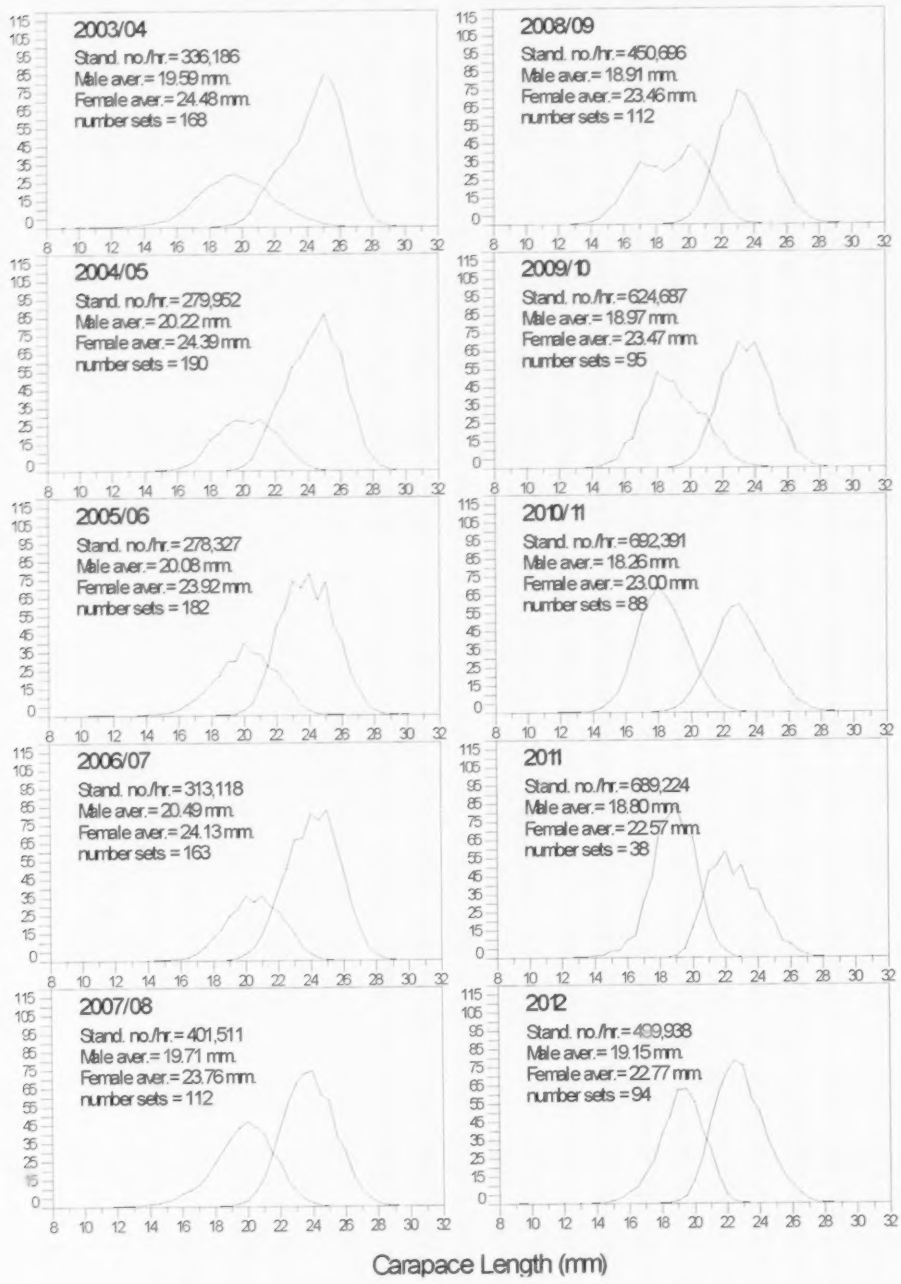


Figure 68 Observed northern shrimp length frequencies (per 000) from the Canadian large vessel (>500 t) fleet fishing shrimp in NAFO Division 2G (SFA 4) over the period 2003-12. Solid lines = males; dotted lines = females. These length frequencies are based upon management year data

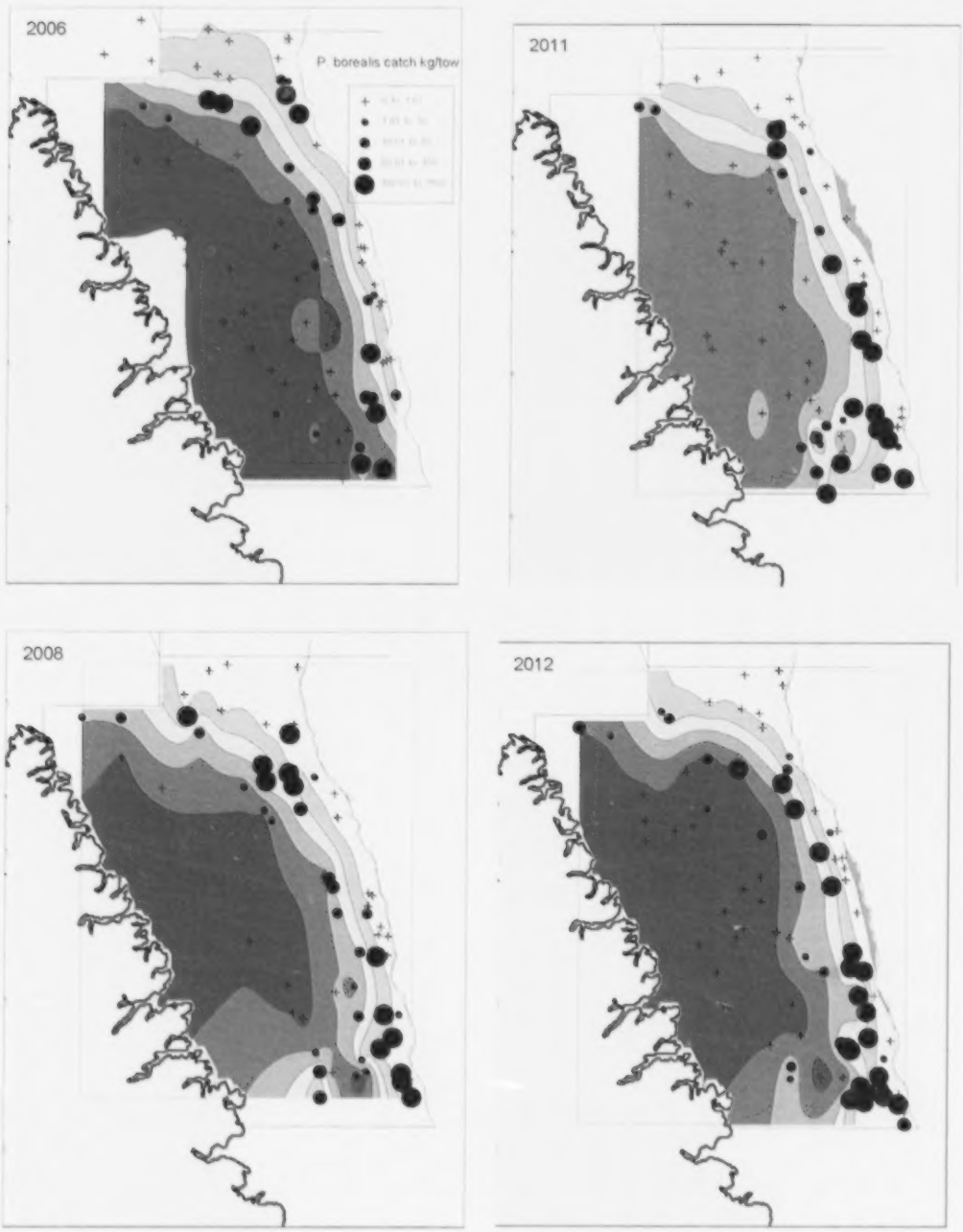


Figure 69 Overlay of SFA 4 Northern Shrimp (Pandalus borealis) catches (kg/tow) upon bottom temperatures as obtained from the NSRF – DFO joint shrimp research bottom trawl surveys conducted over the period 2006-12

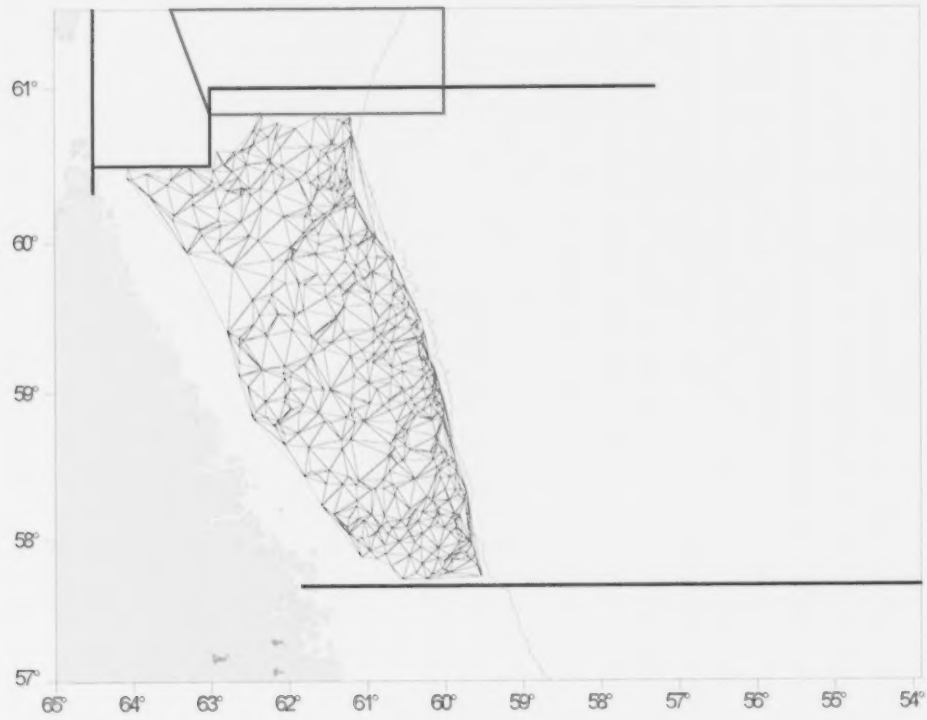


Figure 70 SFA 4 Delauney triangulation used in the Ogive Mapping calculations of survey indices. The blue box is the voluntary closure while the red line is the 1000 m depth contour

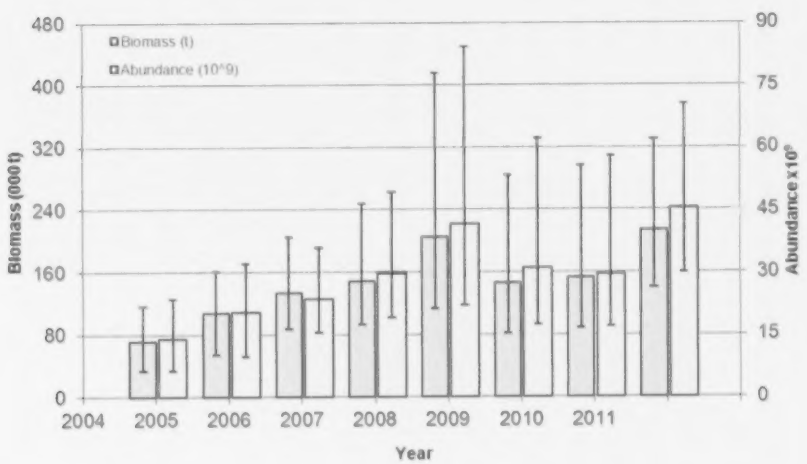


Figure 71 SFA 4 Northern Shrimp (Pandalus borealis) total biomass and abundance indices, as determined from NSRF-DFO joint shrimp bottom trawl survey data using Ogive Mapping calculations

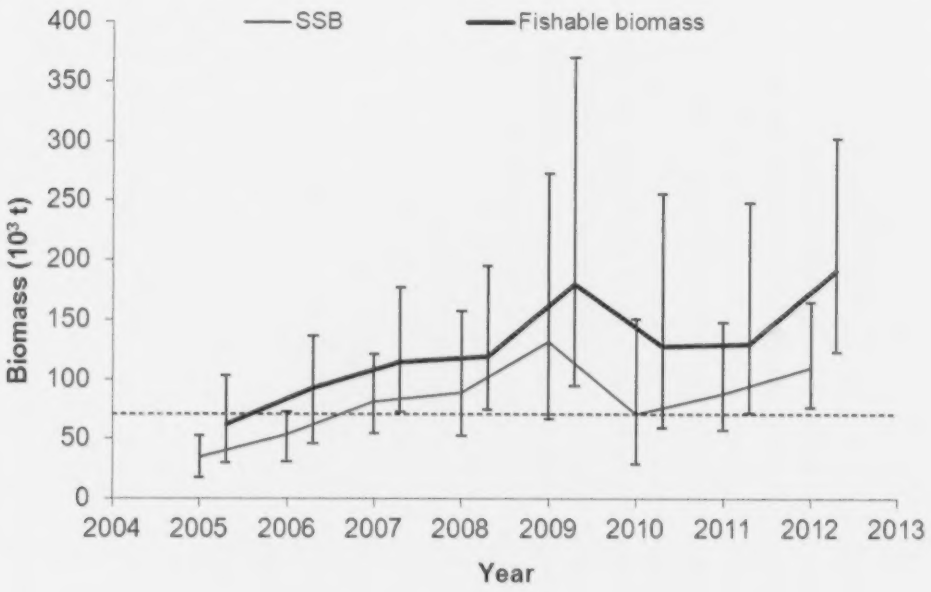
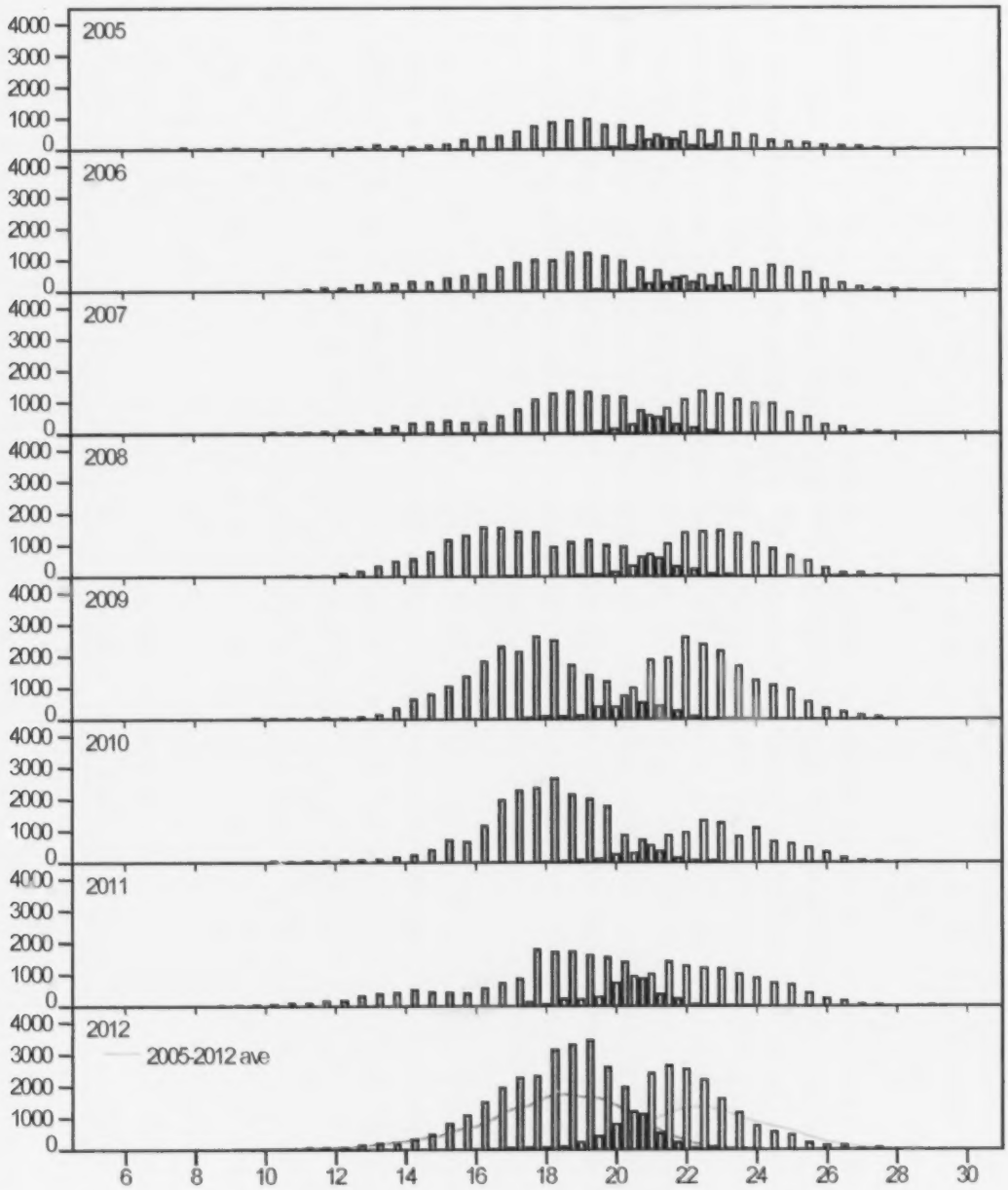


Figure 72 SFA 4 biomass indices (error bars indicate 95 % confidence intervals). The dotted line is the geometric mean of SSB over the years 2005-09 and is used as a proxy for B_{MSY}



Pandalus borealis length frequency histograms (abundance 10^6), 2005-2012; carapace length (mm) (line represents the long term mean; male shrimp are red while female shrimp are green).

Figure 73 Abundance at length for NAFO Subdivision 2G (SFA 4) Northern Shrimp as estimated by Ogive Mapping calculations of NSRF – DFO joint shrimp survey data, 2005-12

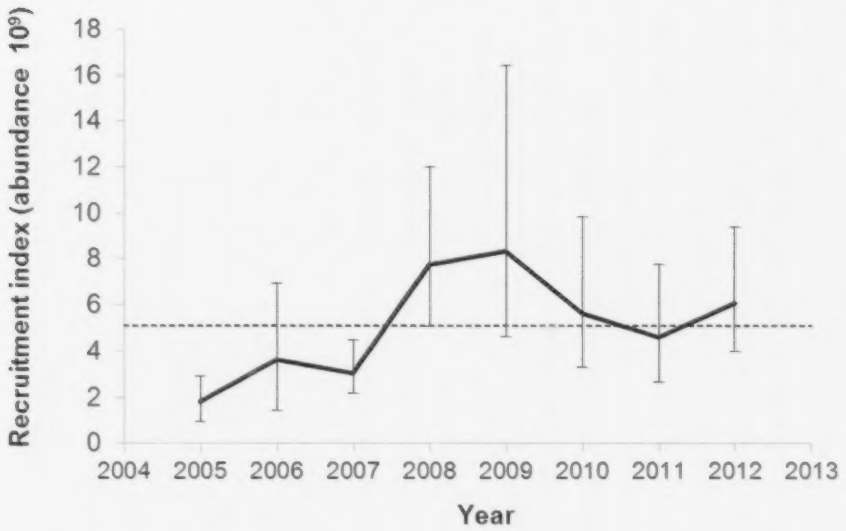


Figure 74 SFA 4 recruitment index (error bars indicate 95 % confidence intervals). The dotted line is the average over the time series

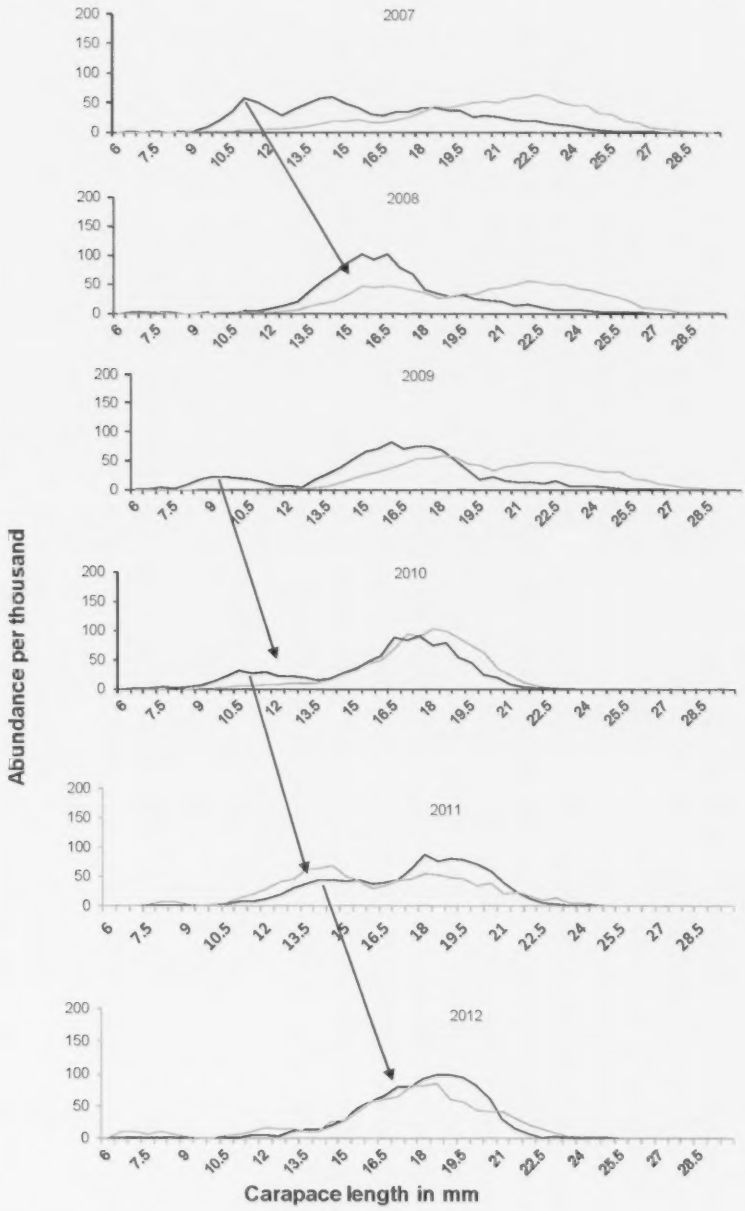


Figure 75 SFA 4 male Northern shrimp length frequencies from the juvenile shrimp net overlain upon male length frequencies from the Campelen codend. Arrows indicate the growth of cohorts from one year to the next

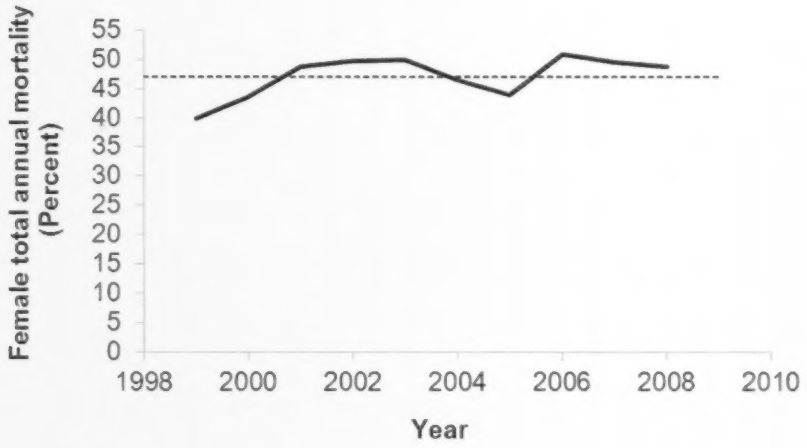


Figure 76 SFA 4 annual female total mortality index based on the observed commercial abundance of multiparous females in year t + 1 divided by abundance of all females in year t, averaged over four years. Year is the third year of the four year period. The dotted line is the average over the time series

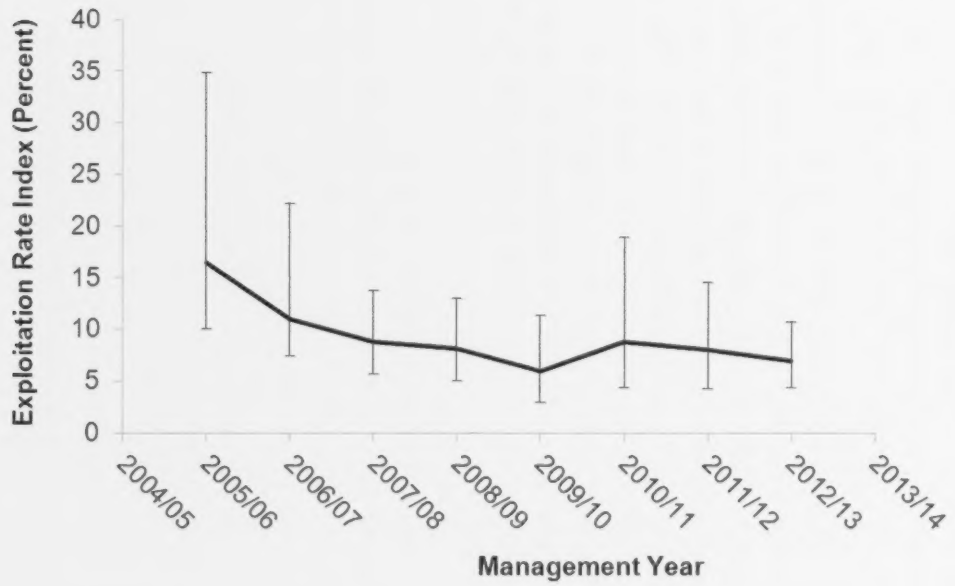


Figure 77 SFA 4 exploitation rate index. (total catch/fishable biomass index from the same year; error bars indicate 95 % confidence intervals)

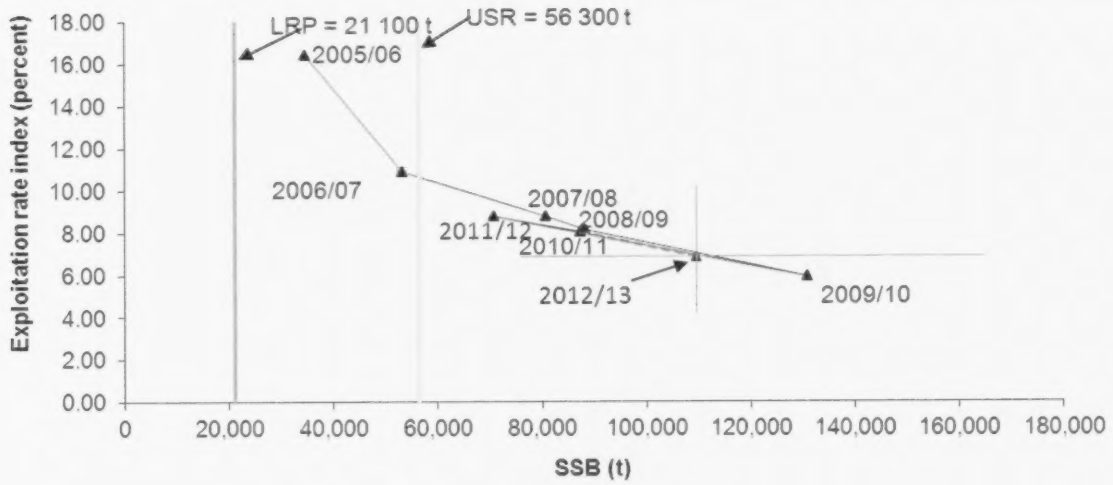


Figure 78 The SFA 4 Precautionary Approach framework with trajectory of exploitation rate index vs SSB. Numbers denote management year. The red cross indicates the 95 % confidence interval for the summer 2012 SSB (horizontal bar), and the exploitation rate for 2012-13 (vertical bar)